WEEKLY | NEWS IDEAS INNOVATION

13 OCT 2007

NewScientist

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THE TRUE NATURE OF BLACK HOLES

SPECIAL DELIVERANCE

Should we save species stranded by global warming?

NANOBODIES

THE CAMEL'S GIFT TO MODERN MEDICINE

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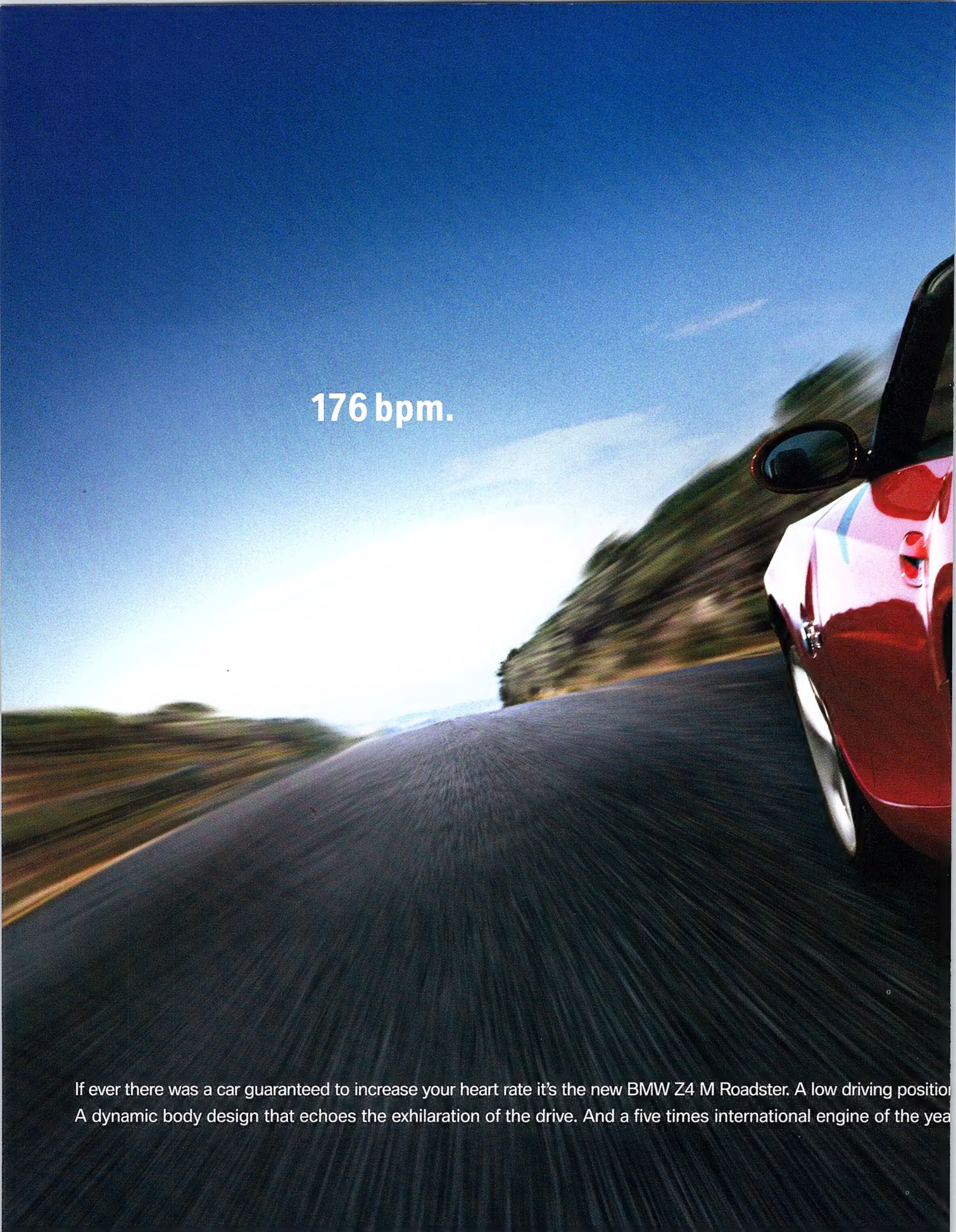

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hat produces an unparalleled feeling of being at one with the road.
class winner at its core powering the whole sensory experience.

The new BMW
Z4 M Roadster

The Ultimate
Driving Machine

Abispa Wasp carries paralysed caterpillar to nest
Raoul Slater

Crystal Orb
Rodney Vella

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for Science Photography
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COVER IMAGE: ANDREW FOSTER MARK HENLEY/PANOS

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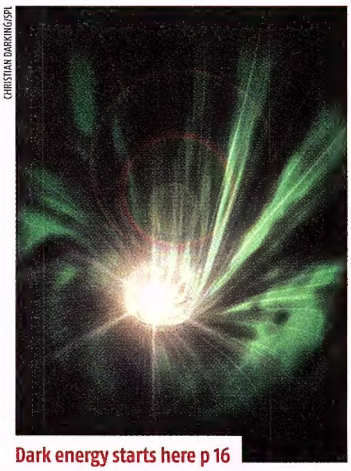

CHRISTIAN DARKIN/SPL

Dark energy starts here p 16

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REGULARS

"As robots develop human-like strengths the trade-off could be that they also inherit our weaknesses"

Watch out for robots that make the same mistakes as we do, page 30

Life has its pressures. Luckily it also has its havens of tranquillity. Settle into the beautifully designed interior of the E-Class and watch stress disappear in the rear view mirror.

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Criticism yes, nonsense no

Climate change sceptics are clutching at straws, and that's bad for everyone

WE NEED climate change sceptics. Not because they are right – at least not on the big issue of human culpability in recent warming – but because they ask hard questions that lead to deeper knowledge. What we do not need from them is misrepresentation and cynical trashing of scientists' work.

Take the latest claims attributed to Fred Singer, arch-exponent of the idea that solar cycles explain everything about climate change, and economist Dennis Avery from the Hudson Institute, a think tank in Washington DC. They made headlines with their list of 500 scientists who they say have refuted "at least one element of current man-made global warming scares". The list, says Avery, "makes a mockery of recent claims that a scientific consensus blames humans as the primary cause of global temperature increases since 1850".

There is sleight of hand in here, and the words "at least one element" and "since 1850" leave plenty of wriggle room. Sadly, some members of the press have chosen to interpret the release as saying that 500 scientists are "doubtful" that present global warming is down to human activity.

Now some of the 500 are demanding that their names be removed from the list. Leading the field is Joanna Haigh of Imperial College London, an investigator of possible solar influences on climate via cosmic rays. She says: "I believe that changes in the sun influence climate, but I have never claimed that solar forcing is responsible for recent global warming. It is mendacious of them to include me in a list of those refuting human activity as the major cause." Another on the list, climatologist Michael Mann of Penn State University, adds: "This is a dishonest and cynical misrepresentation of my findings and views, and those of many of my colleagues."

Singer responded with a note saying: "I was not involved in this exercise – or consulted." Avery explained his interpretations, helpfully telling Haigh: "I carefully avoided saying that you agree with our interpretations."

Once research findings are published they, of course, become public property, available to be contested and reinterpreted by all. But researchers do have a right not to be blatantly misrepresented. Sadly, the spin doctors of climate scepticism have a history of mangling research and traducing the integrity of climate scientists.

Another absurd recent claim attributed to Singer is that "the widely touted 'consensus' of 2500 scientists on the UN Intergovernmental Panel on Climate Change is an illusion: most of the panelists have no scientific qualifications". This stuff is bad not only for science, but also for the sceptical cause. No one wants to silence sceptics: we need scepticism. We just wish they were better at it. ●

The great gene guessing game

WOULDN'T it be great if screening for genes could tell us the diseases we are likely to fall prey to? Then, by making careful lifestyle changes, we could avoid those diseases and live healthily to a ripe old age. A growing band of companies now think we have the knowledge to do this (see page 8). Unfortunately, they have yet to make a convincing case for their claims.

Sure, there are firm links between some individual genes and diseases, including cystic fibrosis and familial hypercholesterolaemia, and with susceptibility to cancers such as breast cancer. But many of the new companies are looking beyond these to gene variants linked by medical studies to conditions such as cardiovascular disease, osteoporosis, thrombosis and obesity.

These diseases are known to arise from the interplay of many genes and environmental factors, and often we understand only one or two of these influences. Scientists cannot agree on how significant many of the screening companies' chosen variants are, let alone whether suggested remedies will work.

Given this uncertainty, the best way to safeguard people's health is for companies in the prediction business to be treated in the same way as pharmaceutical and medical device manufacturers. Their tests and advice should be licensed by independent regulators. In the meantime, why not stop smoking, drink moderately, eat plenty of fruit and vegetables and exercise regularly? You don't need a genetic profile to know this is good advice. ●

Upfront

IT'S COOLER TO BE GREEN

The greenest cities should be, well, green. Leafy walls and roofs could help people turn down the air conditioning on hot days, saving huge amounts of energy. It could lower temperatures by up to 11 °C, depending on the city.

Eleftheria Alexandri and Phil Jones at the Welsh School of Architecture at the University of Cardiff, UK, used computer models to compare the impact of "greening" buildings in nine cities, including temperate London in the UK, humid Mumbai in India, and tropical Brasília in Brazil.

Using temperature data from each city's warmest month, they found that the air would be cooler around every building with green walls and roofs. And the hotter the climate, the greater the cooling effect (*Building and Environment*, DOI: 10.1016/j.buildenv.2006.10.055).

If, for example, a group of buildings in Riyadh, Saudi Arabia, was clad in vegetation, the average temperature in the gap between the buildings would be 9 °C cooler during the day and the top temperature in these spaces would fall by 11 °C. In London and Montreal, peak temperatures would drop by 4 °C.

Green surfaces lower local temperatures in two ways. Firstly, the green surfaces absorb less heat than typical building coverings, and so radiate less heat back into the immediate vicinity. Secondly, plants cool the air through the evaporation of water as they transpire.

Greening buildings is catching on. In Switzerland, for example, roofs covered in alpine plants that require little soil are increasingly popular, while wall-climbing plants adorn homes in many countries.

MORLEY VON STERNBERG/ARCAID

Street life

Politics of ET life

WE HAVE yet to set up home on another world. The sheer logistics of such a move are far from understood, and no one knows if we could afford to go anyway. But that didn't stop participants at the International Astronautical Congress in Hyderabad, India, last week from discussing how such bases should be governed.

Just don't call people living on the moon or Mars "colonists". M. Y. S. Prasad, deputy director of

"The word 'colonies' evokes unpleasant memories of European settlers in India"

the Space Applications Centre in Ahmedabad, says the word "colonies" evokes unpleasant memories of European settlers, so Indian scientists prefer to say "habitation bases".

Democracy should be the political system of choice, and there should be no need for individuals to own property, says William Marshall of NASA's Ames Research Center. Marshall proposes a seven-point system for government on the moon. First, he advocates e-voting; second, a jury system; third, an "upper house" to consider the long-term needs of lunar society. Fourth, he advocates "wikipolitics" – a method of utilising information gathered from a range of sources to reduce redundancy.

Point five, Marshall says, is the use of analytical politics to ensure rational decisions are made to improve the society; six is the use of historical checks to prevent society from repeating its mistakes. The final point calls for "feedback loops" aimed at improving efficiency.

Such a governance system on the moon "could offer tremendous opportunity for political reform", says Marshall, which could in turn produce "huge benefits" if it inspired change on Earth.

Ji Wu, director of China's Centre for Space Science and Applied Research in Beijing listed the reasons why China was interested in establishing lunar and Martian bases, including mining natural resources. But finally, he said, it's "because we just want to be there".

Vaccine pledge

CERVICAL cancer rates are soaring as more women than ever are surviving into middle age in poor countries. Now two companies that make vaccines against the human papillomavirus (HPV) – the cause of the majority of cases – have pledged to provide vaccine at a reduced cost to poorer countries.

At a conference organised by the UN Development Fund for Women in Brussels, Belgium, last week, one of the companies, Merck, also pledged to donate enough vaccine to treat a million women in the poorest countries over the next five years. A course of vaccine is about $360 in the US.

Poor nations account for 80 per cent of the 250,000 women killed by cervical cancer every year. In rich countries, screening to catch the cancer early has slashed death rates. The conference called for more screening in poor nations.

HPV is a sexually transmitted infection, and so the vaccine is targeted at young girls who are not yet sexually active. Older women will need screening for pre-cancerous changes for decades yet.

ALIENS SAVE HAWAIIAN NATIVES

Not all alien species deserve a bad press: birds introduced to Hawaii are saving rainforests by dispersing the seeds of native shrubs.

Because so many of Hawaii's native fruit-eating birds have gone extinct through disease, habitat loss or predation by exotic mammals, rainforest shrubs have lost their usual way of sending seeds to new sites, says Jeff Foster from the University of Illinois at Urbana-Champaign.

Enter the Japanese white-eye and red-billed leiothrix. Foster analysed their stomach contents and discovered that they snacked extensively on native fruit, while seed traps revealed that the birds are dispersing the seeds widely, allowing native shrubs to reclaim the "understorey" of Hawaiian forests (*Conservation Biology*, vol 21, p 1248).

"People tend to think of native species as good and exotic ones as bad, but it's just not that simple," says Foster.

Missing out?

ALMOST a third of American children swallow vitamin and mineral supplements – but it's still not clear whether they're getting enough.

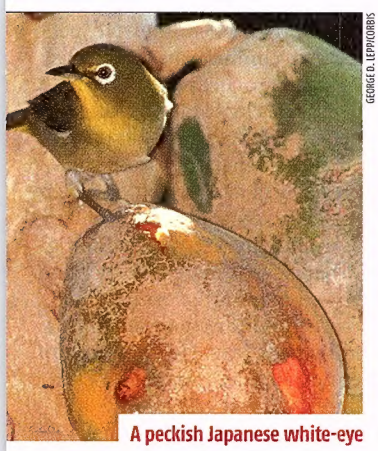
Mary Frances Picciano and her colleagues at the Office of Dietary Supplements in Bethesda, Maryland, analysed the results

"Supplement intake was highest in rich homes, but it's not clear if poor kids go short"

of interviews with 10,136 children, which were designed to track trends in the American diet. She found that 32 per cent of children had taken supplements in the 30 days prior to their interview. While supplement use peaked at 49 per cent for five-year-olds, it declined to about 20 per cent in mid-teens, then went back up to 28 per cent in young adults (*Archives of Pediatrics and Adolescent Medicine*, vol 161, p 978).

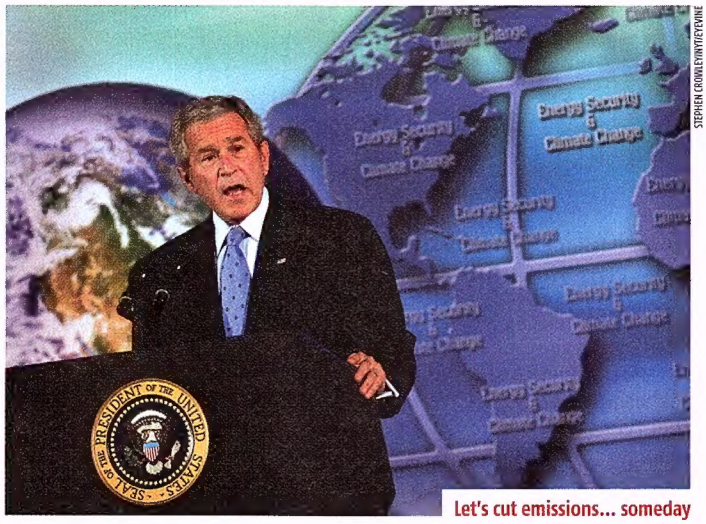
Supplement consumption was highest in richer households, but Picciano says it is too early to conclude that rich kids take too many supplements while poorer kids go short. "It's highly implied, but we won't know for certain until we complete our further analysis of their diet," she says.

An estimated 57 per cent of American men and 47 per cent of women take dietary supplements.



GEORGE D. LEPP/CORBIS

A peckish Japanese white-eye



STEPHEN CROWLEY/NYTIMES/EYEVINE

Let's cut emissions... someday

Carbon convert?

AFTER years of denial over global warming, President George W. Bush now seems willing to tackle the issue – in words, at least. And he has army backing: "Climate change is and will be a significant threat to our national security and in a larger sense to life on Earth," said General Gordon Sullivan, former chief of staff of the US army in written testimony to Congress on 27 September.

The next day, Bush hosted a

"Two-thirds of Americans would support a treaty requiring emissions cuts"

summit of representatives from leading greenhouse gas emitting nations at which he called for curbing emissions to be made a long-term goal. He repeated his opposition to a mandatory cap on emissions, however. Each nation must decide for itself how to achieve results, he said.

Despite the president's opposition to mandatory cuts, the results of a nationwide poll this week found that 68 per cent of Americans would support an international treaty requiring the US to cut its emissions of CO_2 by 90 per cent by 2050. The poll was conducted by Yale University, Gallup and the ClearVision Institute.

As the president spoke at the White House, it emerged that the greater metropolitan area of Washington DC alone produces more CO_2 than Hungary, Finland, Sweden, Denmark and Switzerland combined, according to a report released by the Metropolitan Washington Council of Governments, along with calculations made by *The Washington Post*.

Melting away

THE extent of the Arctic melt this year has been revealed – and it is worse than anyone thought.

Last month, just 4.28 million square kilometres of ice covered the Arctic ocean, 23 per cent less than the previous record low, set in 2005, and 39 per cent less than the average annual minimum between 1979 and 2000. "It didn't just break the record, it shattered the record. This year just obliterated everything else," says Walt Meier, a member of a team of scientists at the US National Snow and Ice Data Center, in Boulder, Colorado, that analysed satellite measurements of this year's melt.

The remarkable decline made headlines last month when European and US space agencies announced that the ice-clogged North-West Passage had completely opened for the first time (*New Scientist*, 22 September, p 4).

Taser turn-off

A year-long trial of Taser stun guns by 10 police forces in England and Wales has lost its biggest participant: London's Metropolitan Police. The Met's civilian governing body, the Metropolitan Police Authority, was prepared to allow the use of Tasers as an alternative to guns on London's streets but not in addition to guns, as the Met has requested.

Unwitting acquitted

Four doctors and a US drug company have been acquitted of negligence following Canada's worst public health disaster. More than 20,000 people contracted HIV and hepatitis C during the 1980s and 1990s after receiving contaminated blood products. This week's trial was brought by seven of them, all infected by a blood-clotting product of Armour Pharmaceutical.

Comet tails

A violent wave of charged particles hurtling from the sun – a coronal mass ejection – has ripped the tail from a comet that was passing close by. Comet Encke was within the orbit of Mercury when it felt the sun's wrath. The disrobed comet was spotted by NASA's STEREO spacecraft on 20 April.

Nukes for NASA

The space agency intends to boost its use of nuclear power in craft designed to fly to hard-to-reach parts of the solar system, and also to power robotic exploration, *Aviation Week* reports. Nuclear power for space is controversial because of launch safety concerns.

Pubs with atmosphere

Three months after England banned smoking in enclosed public spaces, levels of tobacco smoke in pubs have dropped by 95 per cent. In addition, levels of cotinine – a breakdown product of nicotine – in the blood of bar staff have dropped by 75 per cent, according to research presented at the UK's National Cancer Research Institute conference in Birmingham this week.

This week

Genetic testing: an informed choice?

Commercial tests could influence how you live your life, but do we know enough to make the right decisions?

ANDY COGHLAN

"BY KNOWING your profile you can take control of your life and your health."

So says the website of Genetic Health, a UK company offering genetic tests for a variety of diseases, including cancer, osteoporosis and blood clots – in exchange for an £825 fee.

Genetic Health may be one of the first UK companies offering such tests, but it is certainly not alone globally. In recent years there has been an explosion of companies offering consumers a genetic insight into their fate, based on a simple cheek swab or urine sample. In some cases, companies offer personal remedial advice and nutrients to counter the effects of any "bad" genes they identify.

The companies offering the tests don't have to have them checked or approved by regulatory agencies. They don't even have to prove that the tests and advice they offer are scientifically valid or clinically meaningful.

That could be about to change. This week European regulators met in Paris to debate "over-the-counter" genetic tests, while in the US – where the majority of genetic testing companies are based – regulators and company chiefs met in Washington DC last month to discuss the same issue. "There is now global consensus that gene tests need to be subject to independent pre-market evaluation," says Stuart Hogarth of the University of Cambridge, who has been assessing the lack of regulation internationally. "In every country, there's some kind of regulatory gap through which gene tests fall," he says (see "Neither drug nor device").

You don't need a genetic test to tell you which is healthier

There's no doubt that genetics influences disease risk to some degree. Several predictive medical tests for single-gene inherited diseases and certain cancers have been exhaustively researched and fully approved by regulatory authorities. These include tests for the *BRCA1* and *BRCA2* genes, whose presence increases the likelihood that a woman will get breast cancer by between 50 and 80 per cent.

Lifestyle genetics

The difference between these tests and so-called "lifestyle" gene tests for common diseases is that in the case of heart disease, for example, a large number of genes – each of which has only a small influence on disease risk – are likely to be involved, and there may be other confounding factors as well. "Scientists are beginning to realise that shared lifestyle and environmental factors might be more important than genetic influences," says Helen Wallace of GeneWatch, a UK-based genetics public interest group.

By focusing solely on the

NEITHER DRUG NOR DEVICE

Predictive gene tests sold directly to the public slip through the regulatory net because they're neither standard pharmaceuticals nor medical devices – both of which are regulated in most developed countries.

"So how do you ensure companies tell the truth about their products?" asks Stuart Hogarth of the University of Cambridge. What is needed, he says, is for a regulatory agency such as the US Food and Drug Administration (FDA) to step in and pull a product from the market if the test is found wanting, or stop it from coming to market in the first place.

The FDA is currently considering how such tests should be regulated, and is expected to make a decision in the coming months. Meanwhile, in the European Union, a directive on in-vitro testing is being revised and could include provisions for the regulation of consumer gene tests.

The need for regulation is becoming more urgent. Last year, the Genetics and Public Policy Center (GPPC) at Johns Hopkins University in Baltimore, Maryland, compiled a list of 17 companies offering genetic tests in the US. Some focus on skincare, some on athletic potential, some on weight loss and others on more generalised predictions of disease risk. Some offer dietary supplements and others products to remedy "faulty" genes. Suracell, for example, claims to detect gene variants that impair DNA repair and offers customers customised nutrient formulas to compensate.

Suracell was one of four companies criticised last year in an undercover investigation of predictive gene testing by the US Government Accountability Office (GAO). The other companies investigated – Sciona, Genelex and Market America – were also criticised for misleading consumers by making medically unproven and ambiguous predictions.

In the wake of the GAO report, the US Federal Trade Commission, which monitors suspect trading practices, issued an immediate notice to consumers advising them to be sceptical of companies offering genetic tests. "The advice [they offer] rarely goes beyond standard, sensible dietary recommendations," it said. The FDA's Steve Gutman agreed, telling a Senate committee analysing the GAO report: "The tests largely appear medically unproven and useless."


SERGE KROUGLIKOFF/ZEFA/CORBIS

impact of genes on such diseases, critics fear that the entire field of genetics could be brought into disrepute. Worse, it may distract people from the simple lifestyle changes they can make to counter their risk of disease.

However, Genetic Health's founder, Brian Whitley, defends the concept of genetic testing on both scientific and ethical grounds. "We stick to high-quality, large-scale epidemiological studies published in peer-reviewed journals [to decide which genes to test]," he says. "We accept some studies are later refuted, but that's why we base ours on the strongest and most replicated studies."

Genetic Health, whose portfolio includes tests for cardiovascular disease, lung cancer, obesity and prostate cancer, bases its profiles on 46 key genes. The role of some of these genes in disease is already relatively well established, such as the *ApoE4* gene for cardiovascular risk, the *FTO* gene for obesity and the *F2/V2 Leiden* genes for deep-vein thrombosis (see "Killer genes remain elusive"). However, even for *ApoE4*, doubts exist about its clinical relevance, says Rory Collins, head of the UK's Biobank project, which aims to clarify how genes, lifestyle and environment interact to cause disease. While the *ApoE4* gene variant raises the amount of cholesterol in the blood, potentially leading to blockage of arteries, the jury is still out on the true extent of the gene's effect on cardiovascular disease, Collins says.

Nor is it clear whether other, as yet unidentified genes compensate for "bad" genes. "They are seeing only a small number of variants and saying that's the picture, when the real picture is probably much more complicated," says Gail Javitt of the Genetics and Public Policy Center (GPPC) at Johns Hopkins University in Baltimore, Maryland.

Last month, she and Kathy Hudson, also at the GPPC, co-authored a statement in *The American Journal of Human Genetics* (DOI: 10.1086/521634) calling for the federal government to "ensure the clinical validity of direct-to-consumer tests that make health-related or healthcare-affecting claims".

The need for better regulation is something that everyone agrees on – Whitley included. He says he would like to see the UK Medicines and Healthcare Products Regulatory Agency (MHRA), which approves drugs and medical devices, regulating his product and others like it.

> "Scientists are beginning to realise that lifestyle and environmental factors might be more important than genetic influences"

"The MHRA have copies of all our clinical data," says Whitley. "The science is there, it's not quackery."

Genewatch has sent the MHRA a dossier scrutinising the clinical relevance of all the genes listed by Genetic Health. It trawled the scientific literature for each gene and concluded that only three had large-scale randomised trials and meta-analyses to back them up. The MHRA is currently examining Genewatch's dossier as well as additional evidence submitted by Genetic Health.

Wallace sees Genetic Health as a test case that could herald proper regulation of such companies, as and when they spring up. "The MHRA should be given powers to do pre-market assessments of clinical validity," she says. Hogarth agrees. "We must keep pressing for reform," he says. Otherwise, there's a danger that nothing will happen until there's a scandal and someone gets hurt through following misguided advice, he adds.

> "While the *ApoE4* gene variant raises blood cholesterol, the jury is still out on the extent of its effect on cardiovascular disease"

As for the amount and type of evidence regulators would need to make a reliable assessment, this also needs to be thrashed out.

Wallace questions whether any study could definitively link a specific gene to a defined risk of a common disease. "A split is developing between geneticists who think that bigger studies are needed to quantify risk and those who think that the idea of quantifying risk in the general population should largely be abandoned because we already know that most of the effects are too small to be useful for this purpose," she says.

As an absolute minimum, she believes any study used to justify genetic testing should include more than 5000 people, or be a meta-analysis of similar size. Even then, companies should have to prove – through clinical trials – that any advice or medication they offer actually benefits patients. "Otherwise, how can you know whether it does harm or good," says Wallace. ●

KILLER GENES REMAIN ELUSIVE

Finding the genes responsible for disease has not been easy – even in the case of inherited disorders involving a single gene mutation, such as cystic fibrosis. Identifying gene variants linked with more common diseases is infinitely more complicated – not least because so many people get them, and they must therefore share very common genetic factors.

Here, we list some of the few genes most strongly implicated in common diseases so far.

● Heart disease: People with a variant of the *Apolipoprotein E4* (*ApoE4*) gene overproduce cholesterol, but the clinical effect is thought to be tiny compared with environmental factors such as smoking, unhealthy eating or lack of exercise.

● Obesity: More than 600 genes have been provisionally linked to obesity, but so far only one has any strong evidence behind it. The *FTO* gene was recently shown to raise the risk of obesity by 70 per cent in people with two copies of the gene, and added 3 kilograms to their weight compared with non-carriers.

● Deep-vein thrombosis: Two gene variants have been strongly linked to a higher risk of life-threatening blood clots in veins. One is *Factor V Leiden* – a variant of the gene that makes a blood-clotting protein called Factor V. The other is a mutation of the gene that makes another clotting protein, Factor II.

● Detoxification: Variants of the genes that make liver detoxification enzymes called cytochrome p450s have been linked to a variable ability to break down poisons and drugs. So too have variants of glutathione transferases – enzymes that help clear toxins from the body.

● Breast cancer: The *BRCA 1* and *BRCA 2* variants raise the risk of breast cancer in women by 50 to 80 per cent. However, of the 32 other gene variants that have been linked to cancer, an analysis last year showed none was valid (*Journal of the National Cancer Institute*, DOI: 10.1093/jnci/djj374).

TOMAS VAN HOUTRYVE/PANOS

Nothing to brag about elsewhere

Cuba flies lone flag for sustainability

DANIELE FANELLI

WE DON'T need environmental evangelicals to tell us that sustainable development is a good idea. Yet, if that is our goal, we are heading in the wrong direction – with the exception of Cuba. So says the first study to examine the ecological impact of changing lifestyles around the globe.

An international team led by Mathis Wackernagel of the Global Footprint Network looked at how the living conditions and ecological footprints of 93 nations have changed in the last 30 years.

They used the ecological footprint (EF) index, a tool devised in 1993 by Wackernagel and William Rees, his PhD supervisor at the University of British Columbia, Canada. EF quantifies the area of land required to provide the infrastructure used by a person or a nation, the food and goods they consume, and to reabsorb the waste they produce, using available technology. This value can then be compared with the resources that are actually available to people on a regional or global scale. EF has become a popular index, and was used recently, for example, by conservation group WWF to calculate that two more planets would be needed to support everyone in the world in the manner of the average UK citizen.

However, rather than just measure consumption, Wackernagel and his colleagues wanted to measure how close countries are to developing in a sustainable way. The problem is that "sustainability" is an elusive concept. "Nobody dares to say what it actually means," Wackernagel told *New Scientist*. "We believe we provided a robust measurement."

For each nation with reliable data, they calculated how many planets would be needed to support the global population if everybody adopted that nation's lifestyle as it was in 1978, and in 2003. They then expressed each figure as an Earth-equivalent ratio (EER) and plotted each value against the nation's corresponding UN Human Development Index. The index is a score of between 0 and 1, and is a function of a country's average life expectancy, adult literacy, level of schooling and per capita GDP.

To develop sustainably, the researchers assume a country must have an HDI of at least 0.8 and a maximum EER of 1 (see Diagram). A lower HDI would mean a nation is not developing adequately, while a higher EER means it is gobbling up too many resources.

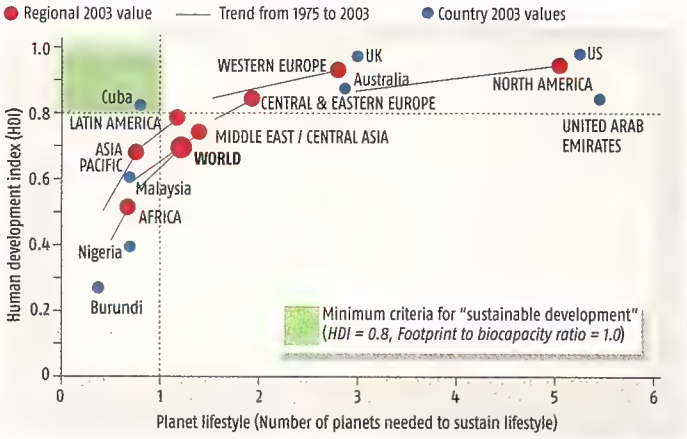
By looking at each country's historical trajectory, a clear pattern emerges. People everywhere have a better lifestyle, but their footprint is growing at a rate proportional to their wealth. Developed countries in particular have done very little to reduce their impact. Only one nation, Cuba, is developing sustainably, and probably not for long (*Ecological Economics*, DOI: 10.1016/j.ecolecon.2007.08.017). "Cubans have high life expectancy and literacy, and were forced into a smaller footprint because of the oil embargo," says Wackernagel. "But they are now economically more successful, and will tend to use more resources."

Critics point out that EF calculations do not take into account issues such as pollution from certain toxic chemicals, and place too much reliance on others, such as carbon footprints, which may be alleviated by the invention of new technologies. Even so, "it's a broad indicator of the direction things are moving, and it's an excellent tool for communicating to the public and decision makers," says Jan Vernon, who reviewed the validity of EF for the UK government.

The study, therefore, carries a credible message: we have all moved away from sustainability, and the world has entered ecological overshoot. "We have not taken sustainable development seriously," Wackernagel concludes. ●

ROAD TO ECOLOGICAL RUIN?

Only Cuba provides a decent standard of living for its people without consuming more than its fair share of resources



SOURCE: ECOLOGICAL ECONOMICS

Windscale fallout blew right across Europe

KAREN KASMAUSKI/CORBIS

The plant is still radioactive, 50 years on

AT THE time it was the world's worst nuclear accident. Now, 50 years after the fire at Windscale in Cumbria, UK, on 10 and 11 October 1957, it has emerged that the resulting radioactive cloud spread contamination over large parts of Europe, much further than previously admitted.

The fire raged in the bomb-making reactor for 17 hours, dumping contamination over a large swathe of England. Across the north-west of the country radioactive milk was poured away for several weeks. Researchers in the UK and Norway have now shown that radioactivity was blown east over Belgium, the Netherlands and Germany, and north over Scandinavia.

"The plume extended further east than accepted in previous assessments," concludes a study funded by the British nuclear industry (*Atmospheric Environment*, DOI: 10.1016/j.atmosenv. 2006.12.049). Monitoring measurements from the Norwegian Defence Research Establishment show that fallout "extended farther north over Norway than originally considered" (*Journal of Environmental Radioactivity*, DOI: 10.1016/j.jenvrad.2007.06.011).

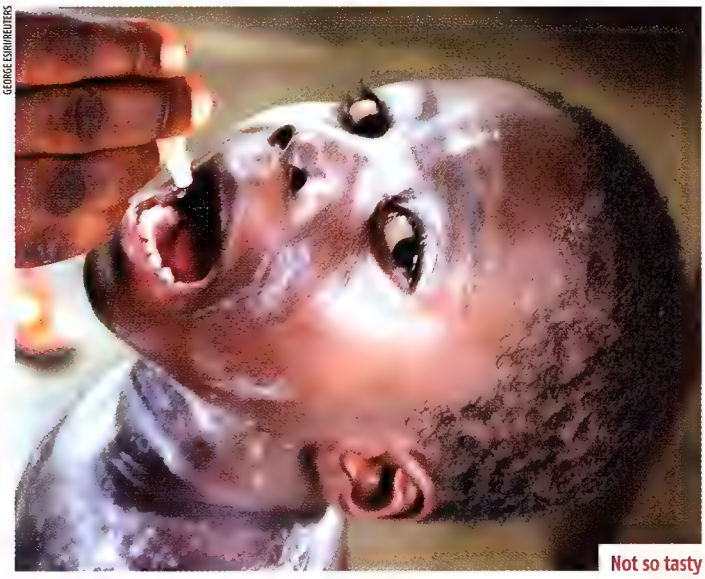
Because Windscale was a military plant, much about the accident was kept secret. The full truth about the large amounts of polonium-210 released didn't emerge until 1983, after it was highlighted in an article in *New Scientist* (vol 97, p 873).

The failure to account for the polonium-210 was "perplexing", says Richard Wakeford, a former British Nuclear Fuels scientist now at the University of Manchester. The isotope is blamed for 70 of the 100 fatal cancers that the accident is officially reckoned to have caused.

The Windscale operation up to 1957 was "an accident waiting to happen," the new report says. "It could have been a lot worse," Wakeford says (*Journal of Radiological Protection*, DOI: 10.1088/0952-4746/27/3/E02).

"The radioactive cloud spread much further than previously admitted, over Belgium, the Netherlands and Germany"

Fifty years on, cleaning up the reactor is still a formidable challenge, with the UK Atomic Energy Authority now designing robots to dismantle the radioactive core. "I am confident that we can develop the prototype to complete this task safely," says the AEA's programme manager, Richard Roper. The aim is to decommission the plant by 2060. Rob Edwards ●



GEORGE ESIRI/REUTERS

Not so tasty

Live vaccine leaves door ajar to polio

DEBORA MACKENZIE

WHEN it comes to eradicating polio, the world is facing a dilemma. Developing countries can no longer be sure that using relatively cheap live polio vaccines will extinguish the virus, yet the replacement killed polio vaccines used in richer developed countries remain too expensive. However, two countries, Indonesia and Mexico are striking out with a new strategy.

The dilemma has been brought into focus by news that a strain of polio the world has already eradicated has re-emerged in northern Nigeria.

In 2003, cases of wild polio virus skyrocketed in Nigeria after its religious leaders denounced vaccination. "Vaccination only really recovered last year," says Bruce Aylward, head of the World Health Organization's polio eradication campaign, and the number of people with polio has fallen with it. This year Nigeria has had 191 cases of polio as of 25 September, compared to 836 by the same date in 2006.

However, in the past two years 93 children were paralysed by type 2 polio, the WHO reported last week. This strain stopped circulating in the wild in 1999, but is still used in some oral polio vaccines (OPVs).

Its re-emergence is not surprising, says Paul Fine of the London School of Hygiene and Tropical Medicine. Children given oral vaccine would have excreted live type 2 vaccine virus in their faeces, and this could lead to infection in children not yet vaccinated. An analysis of the gene sequences of the virus shows that this has happened on seven separate occasions. "That means thousands more were infected," says Fine, as many children would have been infected without displaying symptoms.

"The best way to contain polio in Nigeria is to continue vaccinating, as it cannot spread if everyone is immune"

Aylward says the best way to contain type 2 polio in Nigeria is to continue vaccinating. Oral vaccines work well against type 2 polio, and the live virus cannot spread if everyone is immune. For example, the vaccine-derived polio virus also reached Niger, but it only caused three cases there and eventually petered out.

But the fact that a vaccine that has successfully eradicated polio could also be responsible for its resurgence poses a dilemma – one which may become a growing issue in countries where polio has been eradicated for so long that many people are un-vaccinated, and so are not immune to the disease.

No one really knows what the chances are that the virus in the oral vaccine will turn virulent in this situation. Some people harbour the virus for an unusually long time, and the WHO recently reported that such people are more widespread than previously thought, turning up in low-income countries as well as the industrialised world. "People have debated for years what happens when you stop OPV," says Fine.

We could soon find out. Last month, Jogjakarta province in Indonesia stopped administering oral polio vaccine, and Mexico plans to follow suit soon. Instead, they will give a killed polio vaccine already used in industrialised countries, which they hope will keep people immune while the live oral polio virus disappears from circulation.

However, the killed vaccine costs ten times as much as live oral vaccine, and many developing countries may not want to spend that much on keeping an eradicated disease at bay. But if they do not, they will remain vulnerable to an outbreak.

To break the impasse, scientists met last month in Bethesda, Maryland, to discuss new, cheaper ways of making killed vaccine, and drugs that can clear the virus from chronic carriers. Several candidates are already being tested. ●

SOUNDBITES

"What did the father say? He couldn't say a thing – he just stood there blinking."

New Russian mother **Tatyana Khalina** expresses her spouse's surprise after she gave birth to her daughter Nadia, who weighed in at a colossal 7.75 kilograms – that's 17.5 lbs (BBC online, 27 September)

"This is our way of seeing how God created the universe, and [the Vatican] wants to make a strong statement that truth doesn't contradict truth; that if you have faith, you're never going to be afraid of what science comes up with. Because it's true."

Guy Consolmagno, curator of the Vatican meteorite collection describes how Catholicism has nothing to fear from the discoveries of science. The Vatican is hosting an astronomy conference from 1 to 5 October (BBC online, 27 September)

"It is astounding how all the courts try to evade the question of personhood of a chimp as much as they can."

Martin Balluch of the Association Against Animal Factories in Vienna, Austria, on losing the latest legal battle to get a chimpanzee called Pan declared a "person", so a guardian can be appointed to look out for the ape's interests (Associated Press, 27 September)

"I would not be surprised if we one day find a Marco Polo Neanderthal."

Svante Paabo of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. DNA analysis of fossil bones by Paabo's team reveals that Neanderthals travelled as far as Siberia (NYTimes.com, 2 October)

"The Foton M3 mission is a success."

An over-optimistic **Josef Winter**, of the European Space Agency, on the release of 8.5 kilometres of cable tether from a spacecraft. The cable was supposed to unwind 35 km back to Earth, but it got stuck (*The Moscow News*, 27 September)

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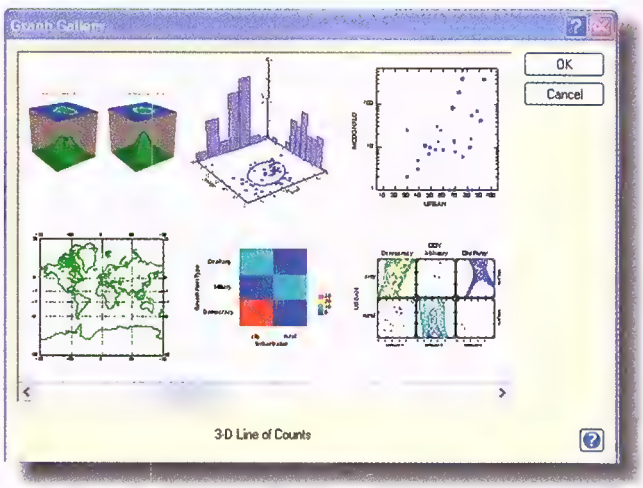

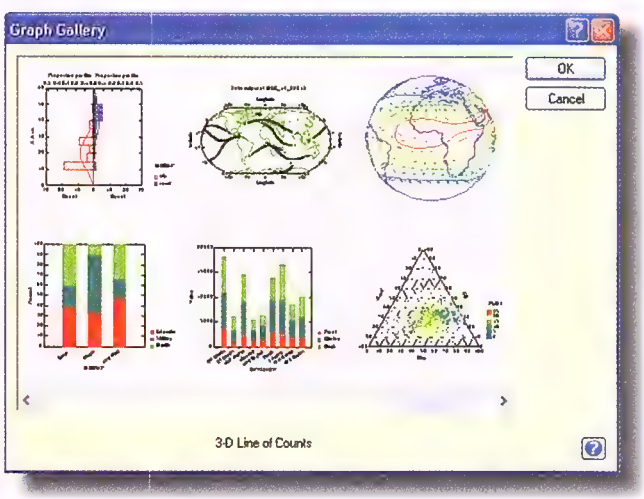

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It's all down to a roll of the dice

MARCUS CHOWN

LOOK around you – at the sun in the sky, a tree swaying in the breeze, a woman walking her dog down your street. You may think all these things have a cause. Einstein did. He hated the idea of quantum randomness underlying everything, which is why he declared, "God does not play dice".

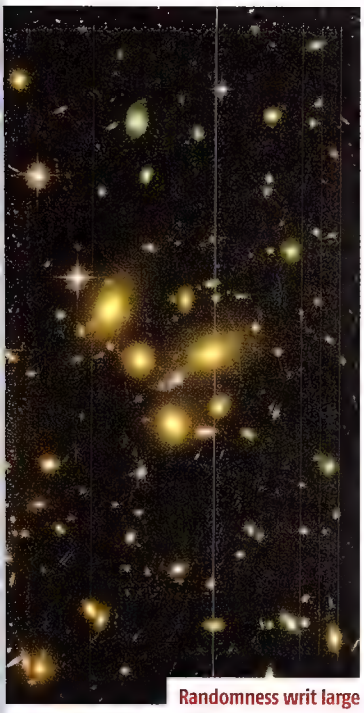
Tough, says Stephen Hsu of the University of Oregon in Eugene. "Not only does God play dice with the universe but, if he did not, the complex universe we see around us would not exist at all. We owe everything to randomness."

Hsu came to his startling conclusion by comparing the amount of information in today's universe with that in the first moments of creation. According to standard cosmology, the universe grew enormously in the first split second of its existence, blowing up from a tiny patch of vacuum. "Because the patch was exponentially smaller than today's universe, it contained exponentially less information," says Hsu.

He has calculated the size of the universe before inflation and before the big bang, and estimated the maximum amount of information it could contain. That space could hold a mere 10^6 bits of information, he says, whereas today's universe requires at least 10^{86} bits. "You have to ask yourself: where did all the information today come from?" he says.

Hsu's answer is that it comes from quantum randomness. Quantum theory is our best description of atoms and their constituents, and it is a characteristic feature of quantum events that they happen randomly, for no reason at all. For instance, the spin of an electron is undetermined until it interacts with its surroundings. The two spinstate possibilities, "up" or "down", are described by one "bit" of information, a quantity which can take on a "0" or "1" to represent each situation. "With 100 electrons, there is the possibility of injecting 2^{100} [or

NASA/STSCI/ESA



Randomness writ large

about 10^{30}] bits – a tremendous amount of information," says Hsu.

So what processes injected information into the universe if the initial state contained hardly any at all? Hsu points to the "inflaton" – the unidentified field or particle which drove the exponential inflation of the universe (www.arxiv.org/abs/0704.1154). The inflaton existed very early on, when the universe was cold. When it decayed its energy went into creating matter and heating it to a ferocious temperature – it created the big bang.

"Like all things quantum, the inflaton field decayed randomly, dumping a different amount of energy into every microscopic patch of space," says Hsu. "It was like a random number generator, injecting a fantastic amount of randomness across the length and breadth of the universe."

The decay contributed much of the information in today's universe. But there was another source too. "Countless quantum events since the big bang, such as the random decay of nuclei and the random emission of photons by atoms, have contributed yet more information," Hsu says.

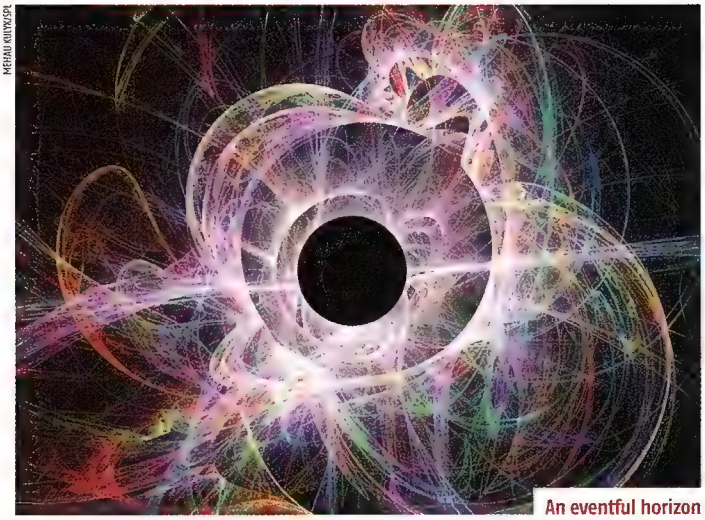
"Not only does God play dice with the universe – if he did not, the complex universe we see around us would not exist"

Interestingly, physicists used to think that quantum fluctuations of the inflaton field provided the seeds which spawned large-scale structures in today's universe, such as galaxy clusters. Hsu goes even further than that. "I'm saying that essentially everything in today's universe is the result of a long sequence of quantum coin tosses since the end of inflation."

Think of a leaf fluttering on a tree. You might think a breeze is responsible, triggered by heat dumped in the atmosphere by the sun, its source, the nuclear reactions in the solar core, and so on. "What I'm saying is that, when you go back far enough, to the ultimate cause of anything, it's a random quantum event, something which happened for no reason."

"Hsu is right – inflation does involve an exponential expansion that essentially creates the whole universe from a little area of space in which there is little initial information and quantum theory rules," says Nick Evans of the University of Southampton, UK.

"The diversity we see around us is created by quantum theory exploring all possible evolutions forwards in time from there." ●



MEHAU KULYK/SCIENCE PHOTO LIBRARY

An eventful horizon

Black hole universe makes dark energy

ZEEYA MERALI

IMAGINE that we live inside a black hole. That could be the key to understanding the origin of dark energy, the mysterious force widely thought to be causing the expansion of the universe to accelerate.

Some physicists have previously suggested that dark energy could arise from the quantum bubbling of virtual particles in empty space, but it wasn't clear how. Now Jae-Weon Lee at the Korea Institute for Advanced Study in Seoul and his colleagues are proposing that dark energy is created as pairs of these virtual particles are ripped apart from each other by the expanding edge of our universe.

According to quantum theory, even the perfect vacuum of space isn't empty: it is a sea of virtual particles, created as entangled pairs of particles and antiparticles which exist only fleetingly and then annihilate each other.

Calculations also show that funny things can happen to these entangled virtual particles when they are near a black hole's event horizon – the boundary beyond which light cannot escape. If one member of a virtual pair crosses the event horizon before it can recombine, its partner will be converted to a real particle. So from the outside, the black hole would appear to radiate particles, a phenomenon known as Hawking radiation.

Lee's team don't seriously suggest that we live inside a black hole, but say that the portion of the universe that we can observe can be thought of in a similar way. Just as a black hole has an event horizon, our observable universe has a boundary known as the "cosmological horizon", which moves as the universe expands. Anything beyond this horizon is hidden because light from there has not had enough time to travel to us.

The team calculated the energy generated when entangled particles are wrenched apart by this "event horizon", and found that it matches the amount needed to explain the acceleration of the universe. "Dark energy is energy observed inside the spherical cosmological horizon," says Lee (*Journal of Cosmology and Astroparticle Physics*, DOI: 10.1088/1475-7516/2007/08/005).

Tomislav Prokopec, a cosmologist at Utrecht University in the Netherlands, finds the idea appealing. "They've come up with an interesting physical mechanism for how [virtual particles] could lead to dark energy," he notes. But he also points out that Lee's model depends closely on the highest energy associated with the virtual particles that contribute to dark energy. "They have chosen a very reasonable value for this, but if it turns out that this value is slightly wrong, it could throw off all their predictions," he says.

Seth Lloyd, an expert on entanglement at the Massachusetts Institute of Technology, is also impressed. "I think they could really be onto something," he says. Now he would like to know whether the model's predictions match detailed dark-energy measurements.

"Just as a black hole has an event horizon, our observable universe has a boundary known as the 'cosmological horizon' "

That could soon be possible. Lee and his team are using their model to predict how dark energy might affect imprints on the cosmic microwave background. This will be measured by the Planck satellite, due to launch next year. "Our model could be easily verified or ruled out soon," Lee says. ●

THIS WEEK 50 YEARS AGO

The space age begins

At 15 minutes past midnight last Saturday morning, engineers at the BBC began checking for signals transmitted to Earth by the world's first artificial satellite, called Sputnik. Every 90 minutes the signals came in on frequencies of 20,005 and 40,002 kilocycles as the satellite swung round the Earth in an elliptical polar orbit at speeds reaching 18,000 miles per hour.

This is a great technical victory not only for the Russian engineers who built and launched this first of many satellites but for scientists the world over who have been predicting their characteristics and behaviour for several years – in the face of considerable scepticism – with what now turns out to be uncanny accuracy.

To place a satellite in orbit requires a razor's-edge balance between the speed of the satellite and the pull of gravity. Too fast and the satellite shoots into space, too slow and gravity pulls it to Earth. No one could know the exact nature of these forces until instruments had been carried into space. So it is a remarkable tribute to the accuracy of the scientists' work that on our first step into outer space the vehicle should be travelling with all the predictability of a tram.

This is, of course, only the first step. The Russian satellite fitted with radio transmitters – as the first American satellites will be – is a tram without passengers. Although the need to conserve their batteries means they may only transmit as they pass over their home receivers, the true purpose of satellites is to serve as a platform in space for instruments telemetering information down to Earth. This has yet to be achieved.

All the same, while the satellite programme is not the most important part of this International Geophysical Year, it will stand as a landmark in progress long after the rest of the year has been forgotten.

From *The New Scientist*, 10 October 1957

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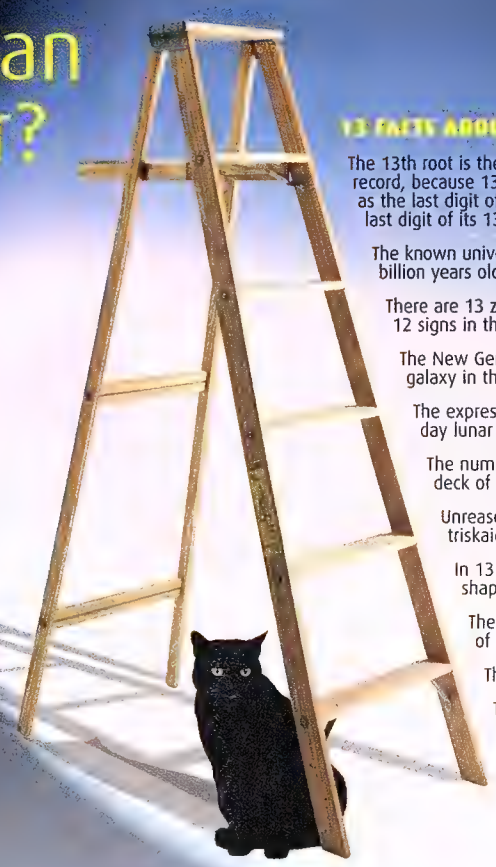

13 FACTS ABOUT 13*

- The 13th root is the most famous integer root calculation record, because 13 is the first prime number over 10 such as the last digit of a 13th integer power is the same as the last digit of its 13th root
- The known universe is currently thought to be about 13.7 billion years old, with an error of about one percent
- There are 13 zodiac constellations, which consist of the 12 signs in the astrological zodiac and Ophiuchus
- The New General Catalogue object NGC 13 is a spiral galaxy in the Andromeda constellation
- The expression "A year and a day" refers to 13 28-day lunar months plus 1 day
- The number of cards in a single suit of a standard deck of playing cards
- Unreasoned fear of the number 13 is termed triskaidekaphobia
- In 13 A.D. Strabo published his view on the shape of the Earth
- The number of dimensions in some theories of relativity
- The number of loaves in a "baker's dozen"
- The 13th moon of Jupiter is Elara
- The atomic number of aluminium
- There are 13 Archimedean solids

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NS07OP14

Immune 'traitors' tuned to kill cancer

COLIN BARRAS

COULD the immune system be reprogrammed to fight cancer? It seems that macrophages – immune cells roped in by tumours to help them grow – can be turned into cancer killers.

Macrophages normally clean up dead and dying cells after an infection. In theory, macrophages should gobble up cancer cells too. "They should [swallow] dead and dying cancer cells, and stimulate an immune response against the tumour," says David Ian Stott of the University of Glasgow, UK.

Instead, cancer cells release chemical signals that persuade macrophages to turn traitor, releasing growth factors that feed the tumour rather than destroy it. "Macrophages are educated by cancer cells to promote tumour growth," says Thorsten Hagemann at Barts and The London Queen Mary's Medical School in London. "If you remove macrophages from mice that are susceptible to cancer, they develop fewer tumours."

The trouble is that removing all macrophages would leave the body vulnerable to infection. "It would be better to alter macrophage behaviour to make

PHOTO TAKE IMG/PHOTOLIBRARY.COM

Macrophages: friend or foe?

them attack tumours," says Hagemann, whose team has been trying to do just that.

They already knew that inhibiting a protein called NF-kB could slow tumour growth, but it now seems that one way it does this is by preventing macrophages from turning into tumour feeders.

Hagemann's team engineered mice to produce macrophages that were missing a gene necessary to activate NF-kB. When they extracted the modified macrophages and injected them into mice with ovarian cancer, these modified macrophages triggered a strong immune response and tumour growth slowed significantly. The results were presented at the National Cancer Research Institute conference in Birmingham, UK, this week.

"The interesting thing is that the modified macrophages behave normally in healthy tissue, but if they are stimulated by tumour cells, they behave differently," says Hagemann. "Instead of expressing molecules that encourage tumour growth they aggressively attack the tumour." Macrophages are one of a growing number of immune cells that researchers are now trying to deploy against cancer. Last month the US Food and Drug Administration approved trials which will involve injecting immune cells called granulocytes from cancer-resistant individuals into people with cancer.

Martin Jadus of the Veterans Affairs Medical Center in Long Beach, California is enthusiastic about the macrophage approach. "If it's true that macrophages can be re-educated to fight tumours, this could be an important advance," he says.

STEM CELLS RECRUITED TO THE DARK SIDE

There is a dark side to stem cells. The restorative properties that could make adult stem cells so useful in tissue repair may also help cancers grow and spread.

Mesenchymal stem cells (MSCs) that are found in bone marrow can differentiate into a variety of cell types, making them prime candidates for stem cell therapies. They usually circulate through the blood system, waiting to be called to damaged tissue to help rebuild it, says Robert Weinberg at MIT.

"But MSCs are also recruited into tumours, possibly using the same recruitment mechanisms as those operating during wound healing," he says.

Now, Weinberg's team has shown that MSCs can enhance the spread of tumours throughout the body. They mixed human breast cancer cells with human MSCs and injected the cocktail into mice. The mice quickly developed breast tumours, and over the course of 12 weeks the cancer spread to their lungs. Another group of mice was injected with human breast cancer cells but no MSCs – they still developed breast tumours, but more slowly, and the cancer did not spread to the lungs (*Nature*, DOI: 10.1038/nature06188).

The MSCs supply chemical cues that "educate" cancer cells to grow rapidly and spread to other tissue, says Weinberg. "It is highly likely that these recruitment and signalling mechanisms will operate in a variety of other tumours," he says.

However, Weinberg think research into the therapeutic use of MHCs should be discouraged. Unless a patient already has a tumour, he says, there is no reason to think introducing stem cells will have negative side effects.

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In brief

CHRIS STOWERS/PANOS

Pick your tea with care, or you risk fluoride poisoning

TEA drinkers beware. Too much of the wrong kind can add significantly to the amount of fluoride you consume, with the tea in just four cups supplying up to one-third of the maximum safe daily amount.

In places where people ingest too little fluoride, it is added to water supplies to strengthen tooth enamel and prevent cavities. But some 200 million people worldwide – mainly in hot countries where deep wells are bored into fluoride-rich rocks, and people drink lots of water – take in too much, and as a result are affected by fluorosis, which makes their teeth brittle and discoloured. In some parts of Sri Lanka drinking water contains up to five times the maximum fluoride recommended by the World Health Organization, and some 98 per cent of people are affected by fluorosis.

Rohaha Chandrajith and colleagues at the University of Peradeniya in Sri Lanka point out that no one has ever assessed the risk of tea, even though tea plants accumulate fluoride from the soil and some Sri Lankan people drink it instead of water. The team found that every grade of local tea yielded a drink with more fluoride than the water it was made with (*Environmental and Geochemical Health*, vol 29, p 429). Just four cups of tea a day would contain 1.36 milligrams of fluoride over and above what was in the water. The WHO's recommended maximum is 4 milligrams.

Ecstasy may inspire drugs to treat anorexia

THE appetite-suppressing side effect of ecstasy may reveal why people with anorexia nervosa can lose the physical urge to eat, despite really needing the energy.

Valerie Compan at the national centre for scientific research in Montpelier, France, and her colleagues wondered if the brain's reward centre – the nucleus accumbens (NAcc), which is stimulated by ecstasy – might also play a role in anorexia.

They stimulated serotonin-4 receptors in the NAcc of mice, which reduced their urge to eat, but also boosted levels of a peptide called CART in the animals' brains. CART levels are also higher in the blood of anorexic women, and drugs like ecstasy are also known to raise CART levels in people.

Blocking the production of CART increased appetite, the team found. And when mice genetically engineered to lack serotonin-4 receptors were given ecstasy, they ate normally, suggesting ecstasy affects appetite through these receptors (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas0701471104).

Compan says the research emphasises that anorexia is more than psychological, and may point to drug targets for its treatment.

Bilingual blur

MOST babies can detect the difference between sounds like "bih" and "dih" by the age of 17 months. Not so children raised in bilingual households, it seems.

Christopher Fennell's team at the University of Ottawa in Canada and his colleagues monitored infants aged 14, 17 and 20 months as they watched a video of two characters: "bih", a plasticine crown, and "dih", a plastic molecule. Later, the babies saw another video, but this time the crown was named "dih". Babies who spent significantly longer looking at the crown were judged to have noticed the difference.

While monolingual babies can detect such differences by 17 months, bilingual babies were 20 months old before they noticed it (*Child Development*, vol 78, p 1510). Fennell thinks the demands of learning two languages mean babies don't notice differences until later – although there is no difference in age at first word.

The last gasp of a dying black hole?

WHAT caused a fleeting but highly powerful burst of radio waves that originated beyond the Milky Way? Suspects so far include the merger of neutron stars and the complete evaporation of a black hole.

The burst was discovered by David Narkevic, a student at West Virginia University in Morgantown, while searching data from the Parkes radio dish in Australia. Finding more such events could help detect ripples in space-time – which should occur when neutron stars merge. These ripples are predicted by general relativity but have never been observed.

In 5 milliseconds the burst released as much energy as the sun puts out in a month. Black holes are supposed to spew out a burst of energy when they die, so that is one possible scenario.

Big teeth, shame about the bite

IT HAD formidable teeth, but the sabre-toothed tiger's bite scarcely did them justice.

Analysis of the skull of *Smilodon fatalis*, a heavily built sabre-toothed cat that lived in North America until the end of the last ice age 10,000 years ago, reveals it could bite with only one-third of the force of a similar-sized modern lion.

A team led by Colin McHenry at the University of Newcastle in New South Wales, Australia, ran CT scans on a sabre-tooth skull and a lion skull. From these, they created 3D computer models of the skulls which they used to test the forces that each could endure, and inflict. A 230-kilogram sabre-tooth could bite with a force of 1000 newtons, compared to the 3000-newton bite of a 250-kilogram lion, the team found (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0706086104).

Modern lions kill large prey by clamping their teeth around their victims' throats and maintaining this bite for up to 10 minutes, slowly suffocating the struggling animal. As a result, a lion's skull must withstand huge forces. "When the *Smilodon* model was exposed to these forces, it lit up like a Christmas tree," revealing intolerable stresses that suggested it could not contend with flailing prey.

McHenry reckons the beefy sabre-tooth probably killed large animals by wrestling them to the ground and pinning their head, before making a deep killing bite to the throat.

NHM LONDON

Caribbean forests warmed to little ice age

COUNTERINTUITIVE or what? The forests of the Caribbean were at their densest for the past 2000 years during the little ice age. How could this period of cooling have led to the forests reaching a peak of growth?

From 1350 to 1850 the little ice age cooled low latitudes and dried the Caribbean. So you might expect to see evidence of this dry spell in the Yucatan Peninsula, says Maria Lozano-Garcia, a palaeontologist at the National Autonomous University of Mexico.

Instead, Lozano-Garcia and colleagues found that the normal dry season was shorter or nonexistent during the little ice age. This was indicated by a sharp increase in the amount of pollen from both lowland and upland forests deposited in core-samples taken from Lago Verde, a small lake about 200 metres above sea level near the southern Gulf of Mexico. Astonishingly, the lake level also rose (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0707896104).

Lozano-Garcia suggests that an increase in winter winds, which boosted dry-season rainfall by blowing moist air up the steep volcanic slopes inland from the lake, may have increased forest growth. Human disturbance probably didn't influence it too much, since few people lived in the area between about 800 and 1920.

Lozano-Garcia says her findings also show that seasonal effects can have an important impact on historical climate change, adding to the evidence that the impact of climate change varies from region to region.

Physicians feel less to heal more

WHEN observing people in pain, doctors suppress the brain circuits associated with feelings of empathy, and bump up activity in areas linked to self-control.

Jean Decety at the University of Chicago, Illinois, and colleagues asked 14 doctors and a group of non-medical volunteers to watch video clips of people undergoing acupuncture or being touched with harmless cotton swabs. Their brain activity was scanned throughout using functional MRI.

Neither group reacted when watching patients being touched with cotton. When the control group watched needles being inserted, however, brain areas associated with pain and empathy "lit up". Those areas remained inactive in the doctors watching acupuncture, but there was increased activity in their frontal brain areas, which are involved in regulating emotions and cognition.

This is the first study to suggest that people can learn to control their "empathy circuits" (*Current Biology*, DOI: 10.1016/j.cub.2007.09.020). It supports the intuitive idea that physicians "toughen up" to avoid feeling personal distress, which could hinder their effectiveness.

HELEN ASHFORD/JUPITER

Look, mum, I can move my mouth

HATE being left numb and drooling after visiting the dentist? A local anaesthetic that targets just pain-sensing neurons could make these trips less traumatic.

Local anaesthetics such as lignocaine work by diffusing into all neurons and blocking channels that transport sodium ions across cell membranes – leaving the person in the dentist's chair pain-free but numb.

Clifford Woolf and his colleagues at Harvard Medical School have now discovered a way of blocking just the pain neurons using capsaicin – the active ingredient in chilli peppers – along with a version of lignocaine that can't diffuse through cell membranes unassisted.

Capsaicin activates the TRPV1 receptor on pain neurons. This in turn opens up a channel on the neurons' membrane, allowing the lignocaine to pass though. The drug then gets to work blocking the sodium channels. In tests on rats the drug combination completely blocked pain without affecting motor function or other senses (*Nature*, DOI: 10.1038/nature06191).

Woolf's team is testing other chemicals that can activate the TRPV1 receptor, since people may not like the initial pain of a dose of chilli pepper. Tests on volunteers are expected within two years.

Keep biodefence honest

The US is teeming with secretive and poorly regulated biodefence labs and it's time the veil was lifted, says **Edward Hammond**

DISTURBING secrets have been lurking in several US biodefence labs. In the past few weeks alone, some major violations of biosafety law at Texas A&M University have come to light, with unreported lab-acquired infections and unauthorised staff handling biological weapons agents among the breaches. Meanwhile, at the University of Wisconsin, Madison, researchers had been working with copies of the Ebola virus genome without adequate precautions.

These violations were not picked up by the US Centers for Disease Control and Prevention (CDC), which oversees all biodefence work carried out in US labs. They were uncovered by the Sunshine Project – a non-governmental group with a staff of two, including me. We work against biological weapons and focus our efforts in the US.

In 2001, President George W. Bush rejected a strengthened international Biological Weapons Convention. Yet soon afterwards, spooked by letters containing anthrax and (false) allegations against Iraq, Congress multiplied the US biodefence budget by 10 and set in motion a huge expansion of labs and staff. Today, the US has some 400 biodefence labs and more than 15,000 people who handle biological weapons agents or, to use their euphemism, "select agents".

My colleague Jan van Aken and I decided to work towards part of what we hoped the strengthened treaty would have achieved. We establish what biodefence labs are up to not by taking their word for it, but by documenting it using public sources of information. For instance, rather than look at a given lab's publications, we find out who is funding its work and what equipment it is buying.

Since 2001, we have filed more than 1000 requests in the US under laws such as the Freedom of Information Act. We ask for safety records, research protocols, funding proposals, committee minutes and more. It has not been easy. Requests are ignored, searches are perfunctory and incomplete, papers arrive blacked out to the point of being unintelligible, and agencies pick fights over search fees. There are a thousand little tricks to derail naive or inattentive requestors of open records.

Some replies have been scary, some amusing. Several times, recipients of our requests reported us to the FBI as possible terrorists. I found myself on the US Transportation Security Administration's watch list of persons who threaten air travel. In some cases, staff told to black out references to biological weapons agents in their lab records clearly had no idea of the subject matter. They dutifully crossed out "anthrax" and "plague", leaving the species names *Bacillus anthracis* and *Yersinia pestis* for all to see.

Despite the spoilers, the documents we asked for have yielded important information. Although the CDC was saying all was well in the country's biodefence labs, we found dozens of institutional biosafety committees (IBCs) – the local bulwarks designed to prevent biodefence research from becoming unsafe or veering into prohibited territory – to be derelict and dysfunctional. We showed that the University of Georgia's IBC had not even met when it allowed the first experiments to resurrect 1918 influenza, or Spanish flu, to move forward with no safety review. If re-creating an extinct organism that killed up to 2 per cent of humanity isn't worth a safety review, what is?

"On several occasions we have been reported to the FBI as potential terrorists"

We hope the violations we have uncovered will demonstrate how important transparency is for safety, and help to fight back against the secrecy of the Bush administration. Texas A&M has been ordered by the CDC to stop all of its research with biological weapons agents and is facing fines that could run into millions of dollars. It has also been dropped from the running to host a new $450 million high-security lab. It's too early to be sure, but the university's predicament seems to be encouraging other labs to confess to their own accidents, which could benefit both lab safety and arms control.

The Sunshine Project will continue its freedom-of-information work, but the problems probably run deeper than we can uncover. Most states do not have public records laws as strong as those in Texas and Wisconsin, but privately funded institutions and universities are not bound by them anyway.

The CDC itself has been an impossible nut to crack. It refuses all requests for information about select agents. Just last week I received its reply to my request for a report of its investigation into Texas A&M. It said it could neither confirm nor deny the existence of such a report, which was ironic, since it had already surfaced and was on the Sunshine Project website.

This week Congress is turning an eye to the proliferation of US biodefence labs. I hope it will overhaul the dangerously muddled group of rules and agencies that each oversee bits and pieces of the biodefence programme. The US does not need 400 labs and 15,000 people working with bioweapons agents, but if this state of affairs must persist then it should at least be made safer and more accountable, both to the US public and to the international community. ●

Edward Hammond is director of the Sunshine Project, based in Austin, Texas

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Letters

Chilled on the Antarctic

From Nicholas Owens, Director, British Antarctic Survey
I would like to reassure readers that the Antarctic Treaty, which regulates activities on the frozen continent, is not under imminent threat as Andrew Donaldson declares (22 September, p 24). The situation is the complete opposite.

The Antarctic Treaty is one of the most successful international agreements ever signed. It has preserved the region as a natural reserve devoted to peace and science for almost 50 years and goes from strength to strength. The original dozen signatories, including the UK, have now been joined by a further 34, the latest being Belarus in 2006. The treaty will not expire in 2009, it will continue indefinitely.

Donaldson accuses the UK of being involved in the rapid development of tourism in Antarctica. This is not the case. Rather, the UK has been at the forefront of developing ways of better regulating and controlling the tourist industry in Antarctica.

The British Antarctic Survey (BAS) is a world leader in research into global science in an Antarctic context. An important part of our mission is to provide the science that underpins the continued environmental protection of Antarctica for the UK government and the Antarctic Treaty nations. For example, we have helped the treaty nations to develop Antarctic shipping guidelines and conservation plans for the most frequently visited tourist sites.

The portrayal of Antarctica given in your editorial (1 September, p 5) was correct and one we fully support.
Cambridge, UK

Super-liars

From Mark Turner
Psychologist Paul Ekman asserted that about 4 to 5 per cent of the population can lie without giving any sign of doing so

(15 September, p 54). Can the true figure really be so low?

Can he be sure that there does not exist a breed of super-liars so skilled that they have successfully concealed their gift from researchers? After all, if you are a natural-born liar, why devalue the currency and tell the world?

The 4 or 5 per cent may reflect only that proportion of natural-born liars who have chosen to disclose their talents. The rest remain cunningly concealed.

I hope my theory may go some way towards reconciling Ekman's findings with the alarmingly high and expanding proportion of the observable universe known to be populated by lawyers, politicians and estate agents.
London, UK

Whose good life?

From Bill Watson, department of anthropology, University of Kent
Your report on the failure of traditional approaches to saving endangered species comes as no surprise (15 September, p 6).
In my department we long ago abandoned the hope that by simply appealing to aesthetics and morality we would protect biodiversity, especially if this is done in an ethnocentric manner.

We are also sceptical of the appeal of demonstrations of long-term economic benefit, which have been proposed more recently as a solution to the problem.

Rather, the fundamental premise of successful conservation lies in first understanding that protective measures must be embedded in policies which are fully aware of the social and economic circumstances of the area.

Conservationists and anthropologists therefore need to work closely together. In most biodiversity hotspots there is little point in explaining to, or even convincing, central and regional governments that deforestation and uncontrolled development are going to have deleterious consequences for the environment. The essential work needs to be carried on at a local level, implementing and monitoring effective measures and identifying very precisely how the local is connected to the national and the international.

What is required is a long-term engagement with communities, working with local counterparts, learning the necessary languages and understanding religious views and deeply held values. We also need to identify how moral visions, aesthetic principles and economic preferences – in short, notions of the good life – differ from place to place. Appeals to material economic benefit alone are simply not working, not least because it is never clear whose benefit one is talking about, and nor are desktop technical solutions.
Canterbury, Kent, UK

Save us!

From Alex Dolby
Emma Young's feature on fertilising the oceans to sequester carbon from the atmosphere reflects a flaw in the way the proposal to use iron for this is discussed (15 September, p 42).

As she explains, although iron seeding will allow plankton to take up extra carbon dioxide, much of the resulting organic carbon will soon be re-emitted when the plankton are gobbled up, respired and excreted.

But not all of it is lost. The iron in waste products formed near the surface will be absorbed by further generations of plankton, creating an iron cycle. Oceanic plankton eagerly take up available iron and little is wasted. Only when organic material sinks below the lowest level reached by living plankton does the iron it contains drop out of the cycle.

As it falls, much of the plankton debris will be oxidised, releasing the iron at depths where it is not usable. But the carbon dioxide produced will stay down long enough to ease the urgent problems of global warming.

At present, critical scientific opinion on iron fertilisation of the oceans is dominated by conservationists, who complain of humankind's environmental recklessness, using guilt to persuade us to reduce our environmental impact. We marvel at how blue our planet looks from space, not appreciating that oceanic blueness is a lasting effect of life's ancient irresponsibility in oxygenating the planet and locking iron up in insoluble oxides. Within decades we could tint the globe green once more. Or is it already too late to save our planet from the conservationists?
Barham, Kent, UK

Why boldly go?

From Trudi Cooper
In arguing that we must leave Earth to ensure human survival, Richard Gott ignores important moral questions (8 September, p 51). He assumes that it is morally justifiable to expend a large share of global financial and technical resources to ensure the genetic survival of a few human specimens and their descendants.

He assumes that European imperial colonisation provides a supportive analogy for the colonisation of space. Many people, not only in non-European nations, do not see European colonisation as benign or beneficial to the colonised.

Gott argues that the first human on the moon spoke English because of England's earlier successful colonisation of America. This colonisation also

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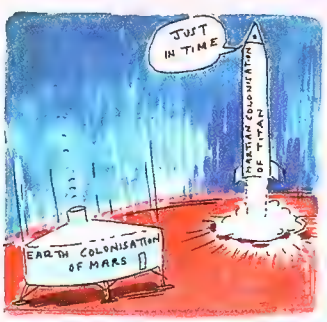
decimated indigenous populations, provided a market for slaves from other colonised populations and destroyed natural environments. European colonists travelled to environments intrinsically supportive of human life and still suffered loss of life that would be morally unacceptable now.

At present, we seem to be engaged in an unplanned experiment to test the limits of our planet's homeostasis.

We would do better to learn more about how the natural terrestrial biosphere sustains itself and how we can work with our own planet to protect what we have.
Joondalup, Western Australia

From Andrew Daviel
Richard Gott suggests that a Mars colony starting with just eight people could double in size every 30 years. This is hopelessly optimistic; larger colonies have failed on Earth, where they could at least breathe the air.

Unless we develop some "magic box", such as a matter duplicator, a colony must either be large enough to make and repair equipment like spacesuits, or depend on imports from Earth.



I suspect that, counting everyone including the janitors in the factory where they make the machines that make the machines, it takes millions of people to make a single microchip – but we don't notice because scale makes them cheap and ubiquitous. Going low-tech on Mars would be impossible – mud huts aren't airtight. I am not saying we should give up: we shouldn't. We just need to prepare properly.
Vancouver, Canada

Out-of-what experience

From Henry Harris
I'm not convinced that Henrik Ehrsson's simulation of an out-of-body experience proves what he says it proves (1 September, p 20). He shows that someone can be fooled into thinking that their self is somewhere else.

He seems to be assuming that the mind is in the body, then saying he has proved that if you think the mind is somewhere else, you're wrong. Unfortunately, his conclusion is based on his assumption, therefore proving nothing except you can perceive yourself as being somewhere other than where your body is.

Experiences of floating near one's own body make up only a small fraction of out-of-body cases. Many involve more distant travel in which the physical body is not seen at all.
Pasadena, California, US

Spooky socks

From Brian Clegg
Nick Webb asks whether a pair of identical twins, one with a red wallet, one with a green, is a working analogy for quantum entanglement (22 September, p 25). The editor's response was "it's exactly right" – but in fact it's exactly wrong. This is the fallacy described by John Bell in his paper "Bertlmann's socks and the nature of reality" (*Journal de Physique*, vol 42, p 41).

Doctor Bertlmann always wore socks of different colours so, seeing that one foot was dressed in, say, pink, you could immediately predict the other was a different colour. In both cases, the information is already in the system. However, quantum wallets, or socks, would be in a superposed state of both red and green. It is only at the point that one is examined and collapses into, say, the red state that the other instantly becomes green, wherever it's located. That's the spooky connection.
Swindon, Wiltshire, UK

From Gary Stanley
The wallet analogy presupposes the redness of one wallet and the greenness of the other to be wholly determined at the outset – that the colour of each is an intrinsic property that is simply revealed upon observation. However, the unique and truly bizarre claim of mainstream quantum mechanics is that each wallet has no "actual-though-hidden-from-view" colour until the moment that either is observed. The wave function then collapses, or the universe splits in two, according to your quantum fancy. Only thereafter does the wallet "really" possess a colour.

If we grant this interpretation for a moment, then we are forced to concede that when one of the wallets is observed, a "spooky" superluminal communication must take place to prompt its equally indeterminate partner to adopt the alternate state. This may sound like an unnecessary overcomplication that seemingly creates a problem from nowhere, but it can be tested. The classic experiments by Alain Aspect in the 1980s were devised to ascertain whether the quantum or the classic interpretation is correct. The results fell in favour of the quantum interpretation.

To be fair, the "local hidden variable" theory beloved of the late David Bohm supports the wallet analogy. However, this is not the majority view among physicists.
Petersfield, Hampshire, UK

Touch the sky

From Patrick Doyle
In a piece on perfect pitch, you write "Mozart had it; Leonard Bernstein had it; even Jimi Hendrix reportedly had perfect pitch..."(1 September, p 20). What did you mean by "even" Jimi Hendrix? It seems an oddly derogatory remark about a musician widely regarded as one of the most talented guitar players of the 20th century.
Toronto, Ontario, Canada

Fission impossible

From Charlie Wartnaby
Ben Crystall describes a scheme "to initiate nuclear fission in... say, deuterium and tritium" (8 September, p 62).

You won't get those to undergo fission, at least not with any energy gain.
Cambridge, UK

The editor writes:
- The scheme we mentioned starts out with fission to generate energy to trigger fusion. One reaction involves antiprotons, uranium, deuterium and tritium, but there are a number of different ideas.

For the record

- **We quoted Philip Boyd describing "multiple research trips with aircraft and helicopters and up to 50 scientists involved..." (15 September, p 44). That should have been "ships", not "trips".**

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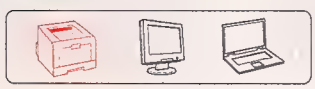


SAMSUNG

GREEN GAS MADE BY THE SUN

Using hydrogen to power vehicles could free us from our reliance on fossil fuels, and water is its obvious source, but how to get one from the other? Now a semiconductor has been discovered that uses energy from sunlight to do this efficiently.

The usual way to get hydrogen from water is by splitting the water molecules with an electric current, but this is inefficient and expensive. For years researchers have hoped to harness sunlight to do the job, using a process analogous to photosynthesis.

Some light-sensitive semiconductors can do this, but they, too, are very inefficient. Now Martin Demuth and colleagues at the Max Planck Institute for Bioinorganic Chemistry in Mülheim, Germany, have found a solar-powered water splitter that does this more efficiently. It still uses only 4 per cent of the visible light that hits it, but that is double previous attempts, says Demuth. What's more, it absorbs the hydrogen it produces, solving the problem of how to store the gas once it is produced.

When Demuth's team suspended the semiconductor titanium disilicide ($TiSi_2$) in water and exposed it to lights that simulate sunlight, they produced hydrogen and oxygen (*Angewandte Chemie*, DOI: 10.1002/anie.200701626). Both gases were initially absorbed by the $TiSi_2$ but could be released by heating. Because the hydrogen is released at a lower temperature than the oxygen, it can be extracted in pure form using gentle heat.

"This may prove to be a significant advance," says photochemist James Durrant of Imperial College London.

PLAINPICTURE

If only they made hydrogen...

Burma, the whole world is watching

CAN high-resolution satellite images increase international pressure on Burma's ruling junta?

After almost two weeks of protests, led by monks, against the dictatorship and at least 13 deaths, it remains difficult to determine what is going on. People used the internet and cellphones to transmit reports and photos, but the junta responded by cutting off internet access.

Now the American Association for the Advancement of Science Geospatial Technologies project in Washington DC has requested images from satellite companies. Human rights groups will use them to amass evidence of violence used to quash protests. They hope to deter the junta from further atrocities and hold them to account. "It will give them a sense that the world is watching," says Lars Bromley of the AAAS.

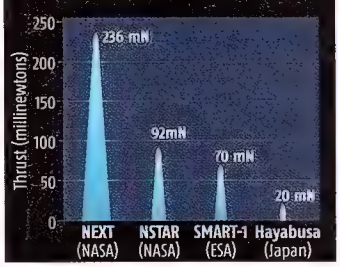
29

per cent of Americans say they will not eat food that has been enhanced with ingredients engineered using nanotechnology

SOURCE: WOODROW WILSON CENTER

RECORD-BREAKING ROCKET

The NEXT engine has set an endurance record for ion motors by firing at 236 mN for 500 days



SOURCE: NASA, ESA

Magnetic stand-in fills GPS gap

A POSITION-finding device that uses the Earth's magnetic field could take over from GPS when no satellites are in view.

Because the angles at which magnetic field lines intersect the Earth's surface are different at every point on the planet, they can be used for location. Previous magnetic sensors were too large to carry by hand and needed liquid nitrogen to keep cool, but now researchers at Virginia Tech in Blacksburg have created a device just 10 centimetres across (*Applied Physics Letters*, vol 91, p 12,3513).

At its heart is a piezoelectric layer (PZT) stuck to a material called Metglas, which changes length in response to a magnetic field. The Metglas pulls the PZT with it, generating a voltage. Three perpendicular sensors mean that all components of the Earth's magnetic field can be combined to give the angle of the field lines.

GIZMO

Games designed to relax their players can now be played on the go thanks to the Personal Input Pod, created by Vyro Games of San Jose, California. Squeezing the thumb-sized pod allows it to measure the electrical conductivity of your skin, which increases with stress. The results are sent via Bluetooth to a phone running games software. The higher the stress, the harder the game, encouraging you to relax.

IRobot, the Massachusetts-based maker of the robotic vacuum cleaner Roomba and mop Scuba, has launched two more household robots. Controlled over the internet, ConnectR roams the home and lets you point its webcam at the kids or the cat to make sure things are OK. It also allows you to chat via its phone. Meanwhile, remote-controlled Looj will clean your gutter, so you needn't climb ladders.

"Japanese people aren't going to take to the culture of Second Life"

Kunimasa Hamaoka of Transcosmos, a Japanese company that has launched Meet Me, a buttoned-down, sex-free online world that is set in a virtual version of Tokyo. Transcosmos is banking on the Japanese rejecting Second Life's lawless, anything-goes culture (Associated Press, 27 September)

Baby's errors are crucial first steps to a smarter robot

If they are to become as intelligent as humans, robots need to make the same kinds of mistakes as we do

MICHAEL REILLY, LISBON

WHEN your software crashes, you probably restart your PC and hope it doesn't happen again, or you get the bug fixed. But not Rachel Wood. When a program she was testing screwed up a task that a 2-year-old would find easy, she was elated.

The reason for this seemingly perverse reaction is that Wood's program didn't contain a bug, but had committed a famous cognitive goof identified by the psychology pioneer Jean Piaget. Known as the A-not-B error, it is made by babies between 7 and 12 months old and is seen as one of the hallmarks of fledgling human intelligence.

Wood's robot has a brain far simpler than a baby's. But unravelling the events that led to this human-like behaviour – something that is easier to do in a computer program than a real brain – could help improve our understanding of artificial intelligence.

It's not the only machine that has exhibited an exclusively human flaw. Last week researchers at University College London announced that they had created a computer program that falls for the same optical illusions as a humans (see "Shared illusions"). It also highlights an idea we may need to get used to: as robots develop human-like strengths, the trade-off could be that they also inherit our weaknesses.

That may be no bad thing, says Wood. In humans, mistakes are often signs of robust ability at another task. So re-creating software, and eventually robots, that make human-like cognitive mistakes might prove to be a critical step towards building true artificial intelligence.

The A-not-B error is made by infants when a toy is placed under a box labelled A while the baby watches. After the baby has found the toy several times, it is shown the toy being put under another nearby box, B. When the baby searches again, it persists in reaching for box A.

Developmental psychologists have some ideas about why babies make this mistake. Linda Smith at Indiana University in Bloomington argues that human intelligence relies on a balance between memories of past experience and the ability to adapt on the fly to changing circumstances. So for example, driving a car without remembered skills such as shifting gears would be farcical. The same would be true if a driver could not adapt to new situations such as a puncture. "Intelligent behaviour requires that you have stability – which you get from past experience – and flexibility so you can turn on a dime when you need to," Smith says.

Smith thinks that babies commit the A-not-B error because they have the ability to store information but can't yet adapt quickly to new circumstances. "Stability gets solved first, but babies haven't got to flexibility yet," she says.

To test whether software programs could make the same mistake, Wood and her colleagues designed an experiment in which A and B were alternate virtual locations at which a sound could be played. A simulated robot, which existed in a virtual space, was instructed to wait a few seconds and then to move to the location of the sound. The process was repeated six times at A, then switched

"In humans cognitive mistakes are often a sign of robust ability at another task"

IMAGE SOURCE/JUPITER IMAGES

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and performed six times at B.

The first time the team carried out the test, the robot's brain was a standard neural network, which is designed to simulate the way a brain learns. It makes connections between "neurons" and determines how often they fire so that the robot can complete the task at hand. That robot successfully navigated to A and then, when the source was switched, simply moved to B.

Next Wood used a form of neural program called a homeostatic network, which gives the programmer control over how the neural network evolves. She programmed it to decide for itself how often its neurons would fire in order to locate sound A, but then to stick to those times when it later tried to locate sound B, even though they might not be the most efficient for that task.

This is analogous to giving the network some memory of its past experiences. And this time the results were different. Wood found that the simulated robot persisted in moving towards A even after the source of the sound had switched to B. In other words, it was making the same error as a human baby.

What's more, as the robot went through a series of 100 identical trials, the A-not-B error faded away, just as it does in infants after they have made the wrong choice enough times. Wood, who presented the work last month at the European Conference on Artificial Life in Lisbon, Portugal, says this shows that although a robot with the ability to learn from past experiences makes the same mistakes as human infants, it can learn to adapt as well.

If she is right, homeostatic networks, even if they make mistakes, might turn out to be the best way to build robots that have both a memory of their physical experiences and the ability to adapt to a changing environment.

Robots that inherit our flaws are not a bad thing, she says, but rather an achievement. It's like the human tendency to feel wobbly after getting off a boat. Although it is a cognitive error, it is a result of our ability to adapt to being on water in the first place. "Even as adults our cognition arises out of interaction with our environment," she says. "Reproducing behaviours like these in robots will be a major step." David Corning, who helped to create a program that falls for optical illusions, says: "The fact that they make these systematic mistakes is quite exciting."

Additional reporting by David Robson ●

SHARED ILLUSIONS

We've all been tricked by optical illusions. Now a computer program that falls for them suggests robots of the future may be saddled with the same visual limitations.

The program was designed to probe why we fall for optical illusions. Researchers suspect they are a side effect of how our brains detect relative shades of colours in uneven lighting. To overcome any ambiguity, the brain subconsciously analyses images using past experience to try to find the actual shades of objects. Mostly it gets it right, but occasionally a scene contradicts our previous experiences and the brain tells us an object is lighter or darker than it really is, creating an illusion. Until now, however, there was no way of knowing if this theory is correct.

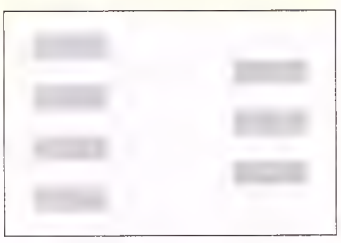
To test it, Beau Lotto and David Corney at University College London created software that determines the lightness of an image based on its past experiences. It was trained on 10,000 black-and-white images of fallen leaves. It had to determine the shade of the centre pixel of each image and then used the feedback it received to make its next decision.

The researchers then tested how well the software would do on the sort of shading that foxes humans. First, the software was tested on images with a light object placed on a darker background, and vice versa. Like humans, the software predicted the objects to be respectively lighter and darker than they really were. It also exhibited subtle similarities to humans, such as overestimating lighter shades more than darker shades. Next, the researchers fed the program images of black-and-white stripes, interspersed with blocks of grey. This time, the program saw the grey as being darker when it was placed on a black stripe, and lighter when it appeared on a white stripe, a phenomenon known as White's Illusion (see below).

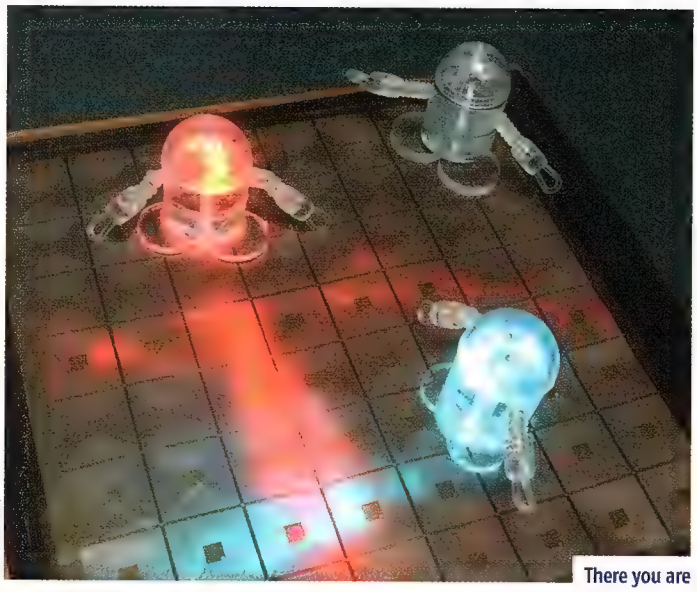
Previous computer models only fell for one of these two illusions, whereas the new software fell for both, making it the most human-like. Since the software's performance was based solely on its past experiences, this supports the theory that our tendency to see illusions is a direct consequence of our experiences. "It's a neat and elegant way of showing that [experience] alone can explain illusions," says vision expert Thomas Serre of the Massaschusetts Institute of Technology.

The work has implications for machine vision. Most research focuses on emulating the human visual system, because it works in a wide variety of environments. Now it seems that if we want to exploit this versatility, we also have to suffer its failings. In other words, it will be impossible to create a robot that never makes mistakes. "It would be helpful for robots to have the same abilities as us," says Olaf Sporns, a cognitive scientist at Indiana University in Bloomington. "But illusions just can't be avoided if this work is correct."

Even if perfection is impossible, the research may help us to improve machine vision systems. While it might be possible to iron out any ambiguities in what the robot sees, Lotto thinks that training robots to do that for themselves could create a more robust system better able to deal with the unexpected – even if it does make occasional errors. "It has the potential to create robotic vision that is robust in the natural world, and to deal with conditions that it hasn't previously had to deal with," he says. Sporns agrees: "I have a hunch that there's a trade-off between robustness and these illusions." David Robson



Smart sheets let gadgets talk through their feet



UNIVERSITY OF TOKYO

There you are

YOU arrive home from work, drop your mobile phone, MP3 player and camera on the kitchen table and pour yourself a well-earned drink. Immediately, the music on your MP3 player begins blaring from your hi-fi, photos start downloading to your PC and texts and emails start flashing up on your TV screen.

What's going on? The phone, MP3 player and camera are sending information to the table, which passes it to the walls, which in turn route it to the hi-fi, television and PC.

Takao Someya, Tsuyoshi Sekitani and colleagues at the University of Tokyo, Japan, have developed a flexible, plastic electronic sheet that can be embedded in tables, walls and floors. Plastic transistors and copper wires that snake through the sheets allow gadgets placed on them to form spontaneous connections and swap data.

The sheets could free users from having to plug gadgets into each other. "I hate cables," says Chris Wren, a specialist in ubiquitous computing at the Mitsubishi Electric Research Labs in Cambridge, Massachusetts. "This allows devices resting on surfaces to discover each other and communicate."

The sheets could also provide more security and be more robust than wireless technologies such as Wi-Fi or Bluetooth, which are vulnerable to snooping and interference from radio signals.

So far the team has built a 21-centimetre-square sheet and used it to send information between two miniature robots (pictured) at a speed of 2 megabits per second. In future, the sheets could be plastered over many surfaces in several rooms around the house.

The square of plastic is divided into a grid of 64 smaller squares or cells. Each one contains a copper coil and three transistors made from the plastic pentacene, and is connected by a copper wire to the edge of the sheet. Each of the gadgets using the system also contains a coil.

When a gadget is switched on and placed on the sheet, the current passing through its coil creates a magnetic field that induces a current in the nearest coil on the sheet. That triggers a transistor in the same cell to create a link between the coil and the wire connecting the cell to the edge of the sheet.

When a second gadget is placed on the sheet on a different cell, the same process occurs. A computer linked to the sheet's edge can then relay data between the gadgets.

The sheets are ink-jet printed, meaning they should be relatively cheap, but before we can have a houseful of communicating devices, the researchers need to miniaturise the computer and find a way to get separate sheets to talk. They will present their work at the International Electron Devices meeting in Washington DC in December.

"This could become the magic wiring that plugs all our devices together," says Wren. **Paul Marks** ●

Will it be plane sailing with self-healing composites?

A SMART composite material that senses cracks as they develop and then repairs the damage could make the next generation of aeroplanes safer.

Composites are widely used in bicycles, fishing rods, racing cars and aircraft, and the first all-composite aircraft – the Boeing 787 and Airbus A350 – are on the way.

A polymer resin typically makes up most of the bulk of a composite, while fibres of a stronger material, such as carbon or glass, are embedded in it to add strength. By varying the type and amounts of resin and fibre, composites are tuned to produce different combinations of lightness and strength.

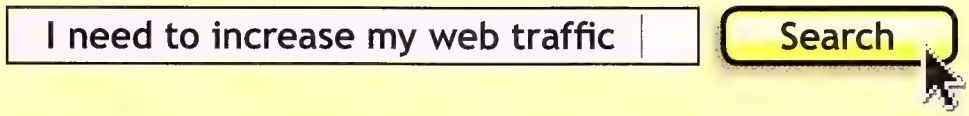
These materials can weaken through delamination, in which the fibres begin to part from the resin. This can be caused by the material experiencing a hard impact, absorbing liquids, or simply getting old. Repeated loading of a composite – caused by the pressurisation and depressurisation of an aircraft fuselage, for example – can turn small delaminations into dangerous cracks.

Now Nikhil Koratkar, an engineer at Rensselaer Polytechnic Institute in Troy, New York, has used the fact that cracks can alter a composite's electrical resistance to develop a self-repairing composite. He made a composite of epoxy resin and carbon fibre containing carbon nanotubes – which increase its electrical conductivity – and sandwiched it between two grids of wires. By applying voltages across the composite at each grid point, Koratkar was able to measure its resistance at these locations. He then made a crack in the composite using a razor blade and scanned each grid point for a second time. The damage increased the resistance at the points nearer the crack, he found. In planes, grids of wires could be snaked around key parts of infrastructure to pinpoint developing cracks.

> **"In planes, wires could be snaked around key parts to spot developing cracks"**

Koratkar has gone a step further by also repairing the cracks. He created a second composite containing a powder with a low melting point, and introduced a similar crack into it. When he passed a current through the sample, it heated up and after 15 seconds the powder melted, flowed into the crack and hardened as it cooled, restoring about half of the original strength of the sample.

Philip Irving, an expert in damage tolerance at Cranfield University in the UK is impressed with the repair time, but says heating could weaken a composite. "The top surface of a wing may buckle," he warns. Paul Marks ●



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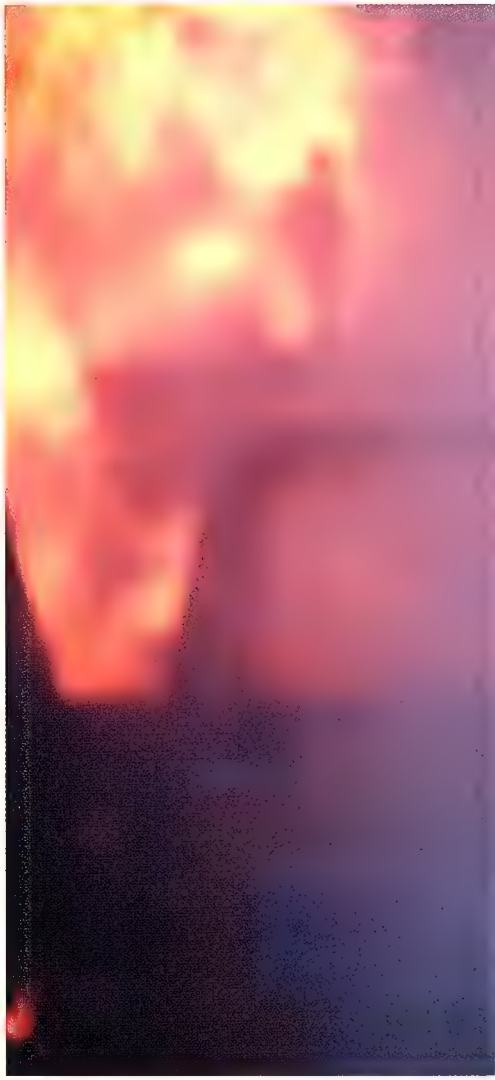
Generation Next

Australia is now setting the pace when it comes to high-speed wireless technology. **David Carroll** reports.



THE FRONT line in a battle with an Australian bushfire is no place for the faint hearted. Confronted by fast-moving and unpredictable flames, fire fighters need courage and a clear head. Just as important is access to information that is timely and accurate, but it is not always the easiest thing to obtain in the remote wilderness areas where fires are often encountered.

Bob Dare, a volunteer with the Country Fire Authority in Victoria, looks after remote fire-fighting operations. Until recently he relied on major CFA stations back in town to hand-deliver maps that helped decide where his trucks and fighters would move. "Those maps were pretty much out of date when they arrived, usually hours later," Dare said. "When we were organised, we'd have a fax machine at our staging area and we'd get the maps quicker, but in scratchy black and white."

Now Dare carries a laptop fitted with a wireless broadband card, which he uses to connect with the Next G™ network, Telstra's mobile broadband network covering 98.8 per cent of the Australian population. Within seconds he can read up-to-date weather information and view accurate maps, putting him and his colleagues on the front foot.

Australia has traditionally been a follower in terms of telecommunication services. But thanks to Telstra and Australia's largest and fastest national third-generation mobile broadband network (3GSM), Australia has become a testing ground for wireless technology, and a source of market research on the way consumers use high-speed services. In the first national rollout of its kind globally, Telstra spent A$1.1 billion to build the Next G™ network in just ten months. The network, which went live in October 2006, has put voice and broadband services within reach of almost the entire country's geographically diverse population.

The Next G™ network can deliver communication, information and entertainment services to mobiles, Palms and other PDAs, or laptops with a peak network downlink speed more than 250 times faster than standard dial-up internet (with typical customer download speeds between 550kbps to 1.5Mbps) . For Australian mobile users, this means improved access to video calls, FOXTEL by Mobile, emails and music downloads, computer users can install a "turbo card" to access the network.

But Telstra's real challenge is to convince people to try the new content-rich applications that the network makes possible.

Mobile television

According to Ross Fielding, Melbourne-based Executive Director of Strategic Planning and Operations for Telstra Product Management, international network providers who are considering their own super-fast mobile networks are particularly interested in how Next G™ users are reacting to FOXTEL by Mobile. Currently it allows consumers to view 16 made-for-mobile television channels on their handset.

Telstra claims the response has so far been encouraging, with the penetration of FOXTEL by Mobile on the Next G™ network being nine times higher than on Telstra's slower 3G 2100 network. Compared to 3G 2100 network users, Next G™ customers are also making eleven times more video calls, watching seven times more videos and downloading three times more music and twice as many games.

High download speeds and wider availability are clearly key to the uptake of the new applications. But Telstra also claims new mobile phone menus developed for the Next G™ network have made it easier for users to access content - challenging conventional wisdom that designers will add more and more features until a product becomes too complex to actually use, so called "feature creep" or "featuritus". Once a phone is opened, one click takes users to a "My Place" menu. One more touch delivers everything from FOXTEL by Mobile to email to the mobile World Wide Web to BigPond® music downloads. "The whole industry is now reinforcing the importance of making new services easy to use," Fielding said. "If the applications and content are easy to use and access, people will pick them up."

Australian mobiles users aren't the only ones making good use of the Next G™ network. Communication companies and mobile phone

The result is improved access to wireless broadband and video calls for the first time in some of Australia's most remote locations. In fact, the network's Extended Range functionality enables the Next G™ network to connect Australia's famous flying doctors, tuna fleets operating off the Great Australian Bight, oil rigs off the Western Australian coast, and miners 95 metres below the ground in the Northern Territory. Deaf people in Darwin are also using the Next G™ network to make video calls to communicate using Australian Sign Language.

Australia should remain at the forefront of mobile broadband technology for some time to come. The Next G™ network was launched with a peak downlink network speed of up to 3.6 megabits per second - five times faster than Telstra's 3G 2100 network. In February, the network was fully upgraded to support a peak network downlink speed of 14.4 megabits per second, with typical customer download speeds from 550Kbps to 1.5Mbps.

Perhaps not surprisingly, for the moment manufacturers are being left in the Next G™ network's wake. But new wireless products capable of operating at peak downlink speeds of 7.2 megabits per second will soon be available, and it will be possible to upgrade most existing devices from companies like Sierra, Maxon, Option and ZTE to the same speed capability.

But the manufacturers will have no time to rest on their laurels. By 2009, the Next G™ network is expected to support a peak downlink speed of 40 megabits per second.

Not even a bushfire moves that fast.

Mobiles and modems capable of operating at peak speeds of over seven megabits per second will soon be available.

manufacturers around the world are taking advantage of its size and speed to test new applications, products and services.

Mountain high

Telstra is also working with companies like ZTE, Samsung, and Qualcomm to undertake advanced testing of new high-speed wireless technologies, with Qualcomm currently having two field teams from the US and Europe working in Australia testing mobile chipsets--basically a bunch of circuits, packed together in one unit.

And in February, mobile handset manufacturer Ericsson installed world-first Extended Range functionality in selected base stations across Australia. The software enables mobile coverage up to 200 kilometres from a base station, up to 120 kilometres more range beyond the standard technical limit of 80 kilometres.

Network Tech Specs

TECHNOLOGY	AVERAGE OR TYPICAL USER SPEEDS	PEAK NETWORK SPEED
2GSM - GPRS	30-40 kbps	96 kbps
2GSM - EDGE	160-190 kbps	236 kbps
3G 2100	180-280 kbps	384 kbps
Next G™ network at launch, using a 3.6Mbps capable device	550-1500 kbps	3.6 Mbps
Next G™ network today, using a 7.2Mbps capable device	550-3000 kbps	14.4 Mbps

Average user speeds are the range of speeds a customer may see in typical coverage locations. Speeds vary depending on location, network capacity, mobile device used, transmission direction and application used.

Peak network speed is the maximum rate the network can deliver data.

The truth about black holes

Are these weird objects what we think they are? We'll soon find out, says **Michael D. Lemonick**

WHAT do we really know about black holes? That may sound like an odd question. Aren't black holes and all their well-known attributes – the singularity, the event horizon, the ability to swallow light and matter – just part of the furniture of astrophysics? Strangely, no. Astronomers know of massive bodies that fit the bill, but for now black holes remain largely theoretical. So much so that some researchers even claim that they don't exist.

The debate over the existence of black holes has been rumbling on since about 1939, when Albert Einstein published a paper arguing that for a black hole to form, a collection of stars would have to orbit each other faster than the speed of light, which special relativity prohibited. That turned out to be wrong, but the point is that black holes are so weird, Einstein didn't believe in them – even though his own 1915 theory of general relativity predicted their existence.

Since then the field has matured. Astrophysicists have solidified their models and identified some promising black hole candidates in the Milky Way and nearby galaxies. So far, however, no one has produced any incontrovertible evidence that these objects fit the classical notion of a black hole: a spinning point of infinite density surrounded by an event horizon from which nothing can escape, not even light.

Such evidence could be coming soon. The technological capability to observe black hole candidates directly and model in detail the complex signals they give off is fast approaching. We will be able to test, for the first time, whether black holes are what we think they are – whether event horizons actually form, what happens to space-time around a black hole and so forth. The stakes are high: far from being merely cosmological curiosities, black holes may hold the key to understanding how galaxies form and how we might merge relativity and quantum mechanics into a "theory of everything".

Indeed, researchers are confident that we will soon know the true nature of black holes. "Before 2005, you'd go to a conference and it would be really depressing. You'd hear one talk after another that went into excruciating detail about why some technique failed," says Frans Pretorius, a physicist at Princeton University who specialises in general relativity simulations. "Now everyone's excited about black holes again."

In the dark

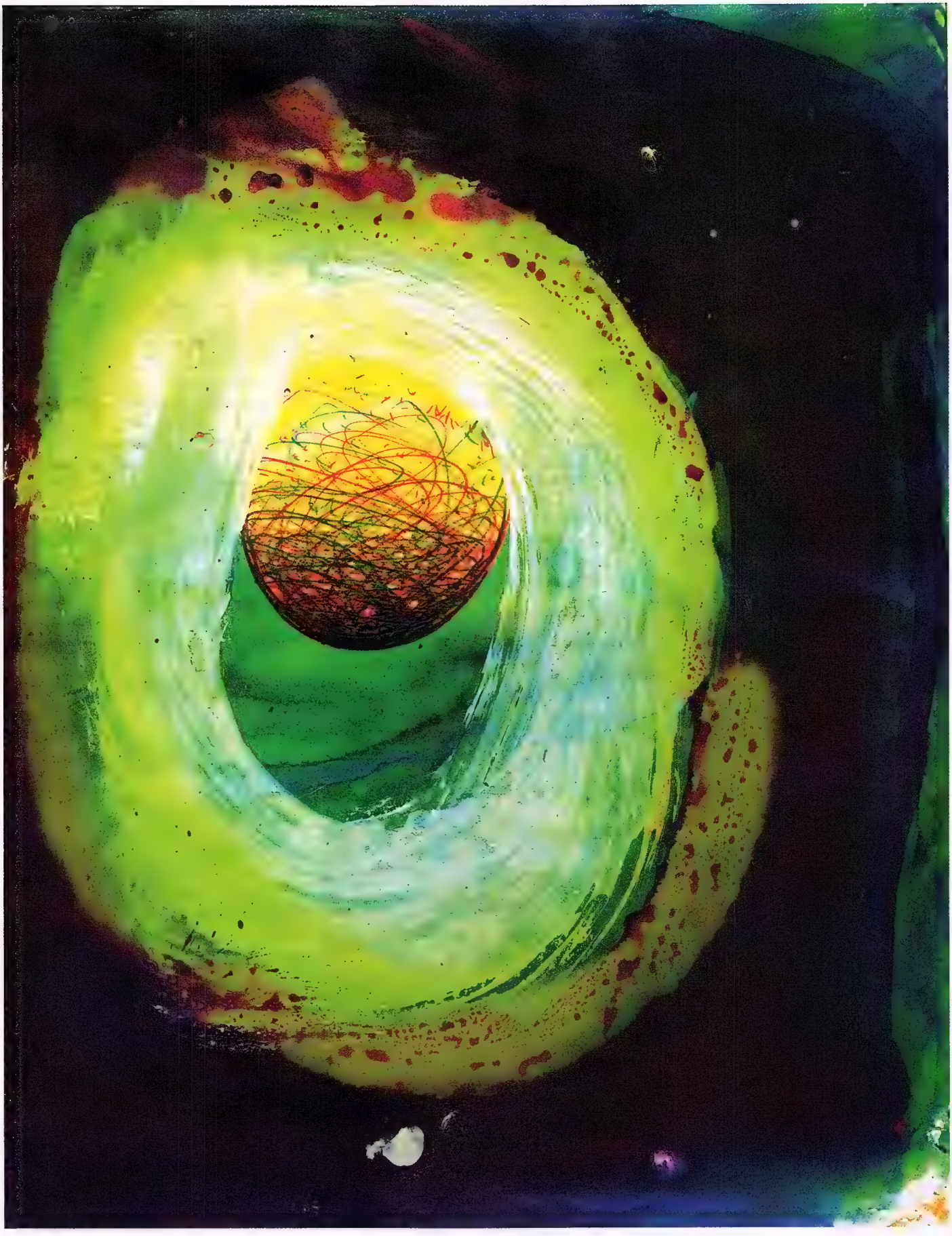
If you count a paper by the Reverend John Michell in 1769, people have known about the possibility of black holes for nearly two-and-a-half centuries. The modern debate began in the 1930s, however, when Subrahmanyan Chandrasekhar and J. Robert Oppenheimer independently showed that under the laws of general relativity these weird objects were necessary to explain what happens when a large star collapses at the end of its life.

So why is it that, seven decades later, we are still in the dark about what black holes actually are? After all, we have ground telescopes that dwarf what was available in the 1930s and space telescopes that see with crystal clarity. We also can see in parts of the spectrum that our grandparents couldn't dream of – X-rays, gamma rays, infrared, radio – where black holes show some of their most impressive features.

The problem is that black holes are so uncooperatively, well, black. That's because a black hole is a concentration of matter so great that its central point, or singularity, has infinite density. The curvature of space around the singularity prevents anything, even a beam of light, from escaping. To make matters worse, researchers showed in the 1960s that in theory all you can ever measure about a black hole are its mass, electric charge and angular momentum, or spin; there is no way to know what originally collapsed to form the hole, and no other way to tell one from another. This led to physicist John Wheeler's quip that "black holes have no hair" – they have no distinguishing features or structure.

So, while most astrophysicists are pretty sure that black holes exist, their blackness and lack of structure means that the observational evidence adds up to only a very strong circumstantial case. "What we do know," says Avery Broderick of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, "is that there are objects within our galaxy and inside nearby galaxies that are too compact and dense to be anything else, barring some unforeseen exotic physics."

Why can't they be anything else? Put simply, they are too dense. Normally, massive objects such as planets and stars don't collapse under their own gravity because there are other forces pushing in the ▶



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opposite direction – chemical bonds between atoms in the Earth, for example, or the outward pressure from electromagnetic radiation in the sun. Classical black holes are so dense that gravity overwhelms all other forces, with dramatic consequences.

Since the 1970s, at least 10 stars in our galaxy have been found orbiting such dense, unseen objects. In addition, many stars and gas clouds are whipping around something at the core of the Milky Way that is generally considered to be a supermassive black hole, and half a dozen nearby galaxies have something similar (see "Black hole contenders", opposite). Astrophysicists have measured the velocities of the stars and gas clouds at the centre of the Milky Way, and using the laws of orbital motion deduced by Johannes Kepler half a millennium ago, they have calculated the mass of the central object to be some 3.7 million times the mass of the sun, all concentrated into a volume much smaller than our solar system. No known material could remain intact at this density without collapsing to a singularity.

In theory, anyway. Now researchers are trying to pin down with observations whether such objects really are black holes in the classical way we imagine them. For the past few years Broderick, who works with Ramesh Narayan's group at Harvard University, has been trying to measure the spin of space-time surrounding the black hole at the centre of our galaxy. Since black holes presumably form from stars or other objects that were spinning in the first place, they should still be spinning – and even faster than the original object, to conserve angular momentum. According to general relativity, spin like this drags the local space-time around with it, and that can be measured, says Broderick, even from far away. If the researchers find the spin effect they are looking for, it would all but confirm the hole's classical nature.

"Measuring the spin of space-time could confirm our classical notions of black holes"

The way they measure the spin effect is by examining the "accretion disc" of gas that builds up around a black hole (see "Are black holes what we think they are?" opposite). This material, superheated by friction as it orbits the hole and tries to fall in, can throw out huge jets of debris so bright they can be seen across the universe. These jets are the hallmarks of massive black hole candidates, with quasars the prime example: they are thought to be jets that happen to point in our direction.

Once jets draw attention to a particular candidate, researchers need to look more closely to pin down its spin. Using high-resolution telescopes, astronomers have previously detected and modelled "hotspots" – bright patches of ultra-hot material – within accretion discs (www.arxiv.org/abs/astro-ph/0509237). Now Narayan's group is planning to look at them in a way that takes advantage of the weird warping of space around a black hole. They know that a light beam aimed horizontally just above the event horizon should whip around the black hole, like a satellite getting a gravity assist from a planet, and fly off in another direction.

But hotspots shine in all directions, not just one. "You see some light that comes directly toward you," says Broderick, "but you also see light that goes around the back of the black hole and comes at you that way." In short, you see a double image of the hotspot, and depending on where in the accretion disc the spot is, you'll see different relative brightnesses between them, which allows you to figure out the local space-time curvature, and from that the spin of the black hole.

The best parts of the electromagnetic spectrum for such observations are the near-infrared and sub-millimetre (between infrared and microwave) bands: plans are afoot to use the Very Large Telescope array in Chile to detect the former, and several widely spaced radio telescopes for the latter. Both sets of observations could be completed within two or three years. If they reveal that space-time is distorted as relativity predicts, it would show definitively that the object in question behaves as a classical black hole should.

Next on the checklist is the event horizon – the point of no return beyond which neither matter nor light can escape. Since a black hole sits in the middle of a glowing accretion disc, part of that disc will lie behind the hole, from Earth's point of view. The light from that part should be blocked, creating a dim patch in the overall glow; the event horizon should be silhouetted against the brightness of the disc. This silhouette would ordinarily be too small to see, like trying to resolve a human hair 200 kilometres away, but a black hole's strong gravity should act as a lens to magnify its apparent size. A non-rotating black hole would magnify the silhouette about seven times, says Broderick, and a rotating one up to 27 times. At that size, he says, we could spot the silhouette with an array of radio

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telescopes – an experiment likely to be performed within a year or two.

Other researchers argue, however, that we should not expect to see event horizons – because they don't actually exist. Earlier this year, physicists Lawrence Krauss, Tanmay Vachaspati and Dejan Stojkovic from Case Western Reserve University in Cleveland, Ohio, made the controversial claim that, in theory, event horizons need infinite time to form. That means black holes as we understand them could never be observed – an assertion that has garnered a fair amount of attention in the field.

The idea is the latest respectable alternative to classical black holes (see "Black hole pretenders", page 40). According to relativity, time slows down for an object, from the point of view of an outside observer, as it accelerates close to the speed of light. Anything falling into a black hole approaches that velocity as it crosses the event horizon. So while someone riding a spaceship across the horizon would feel that he or she was moving at a terrific speed, someone watching from outside would see the ship slow and eventually stop at the horizon, never quite falling in.

If that's true, the same argument should apply to gas, stars or whatever was collapsing to form the black hole in the first place. To an external observer, it would take infinitely long for the black hole to come into being. This is actually a long-standing problem that has never been fully addressed. "People have just assumed it's one of those weird general relativity things and don't discuss it very much," says Krauss. When you add in quantum mechanics, which says that black holes actually radiate particles, the problem becomes even more acute. "If quantum theory says black holes must evaporate in finite time," says Krauss, "and general relativity says they take an infinite time to form, you've got something disappearing before it exists."

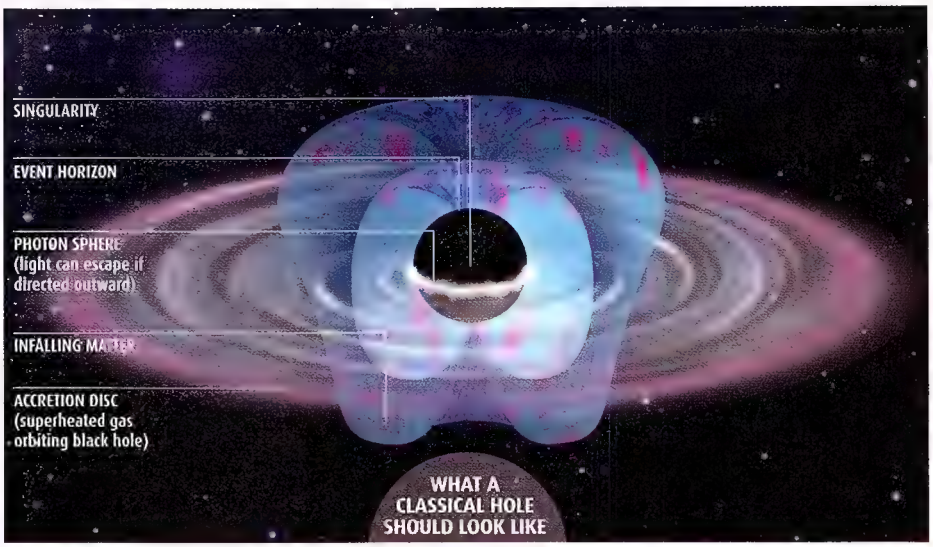
Quantum hole

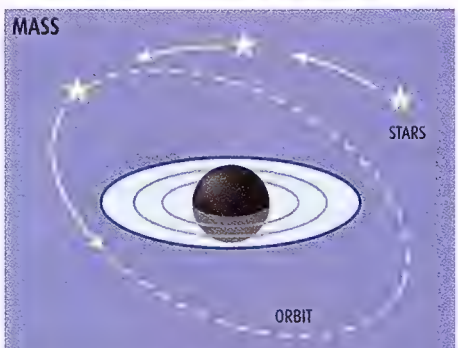
Krauss's work, which will appear in the journal *Physical Review D*, began as an exercise in particle physics (www.arxiv.org/abs/gr-qc/0609024). Researchers had suggested that experiments at the Large Hadron Collider at CERN, the European particle physics lab near Geneva, Switzerland, scheduled to go online next year, could produce energy densities great enough to create a quantum black hole, much tinier than the tiniest subatomic particle. The smaller a black hole, the more quickly it should radiate away its mass, and Krauss and his colleagues were trying to figure out what that radiation might look like.

According to their model, quantum black holes should emit light, X-rays and other ▶

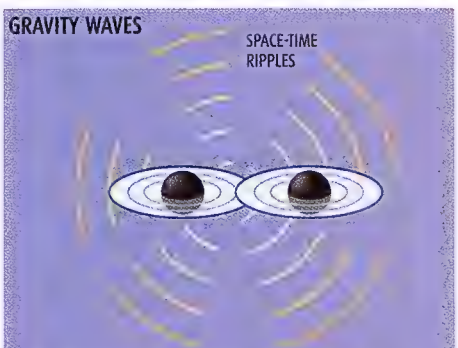
ARE BLACK HOLES WHAT WE THINK THEY ARE?

We can now test whether black holes behave the way general relativity says they should, using new methods and models to measure key parameters such as mass and spin





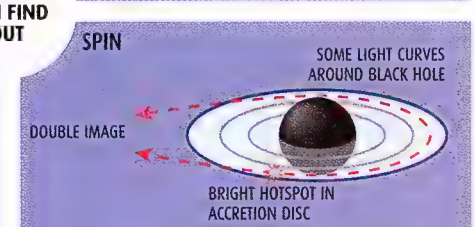
Measuring the velocities and orbits of stars around a black hole reveals its mass. If the mass is concentrated in a small enough volume, no known material could resist collapsing under its own gravity, so the object must have a singularity



When two black holes merge, or if a black hole eats a big star, it might be possible to detect gravitational waves using a sensitive interferometer such as LIGO or LISA. The exact pattern of waves will show whether the objects are classical black holes

HOW WE CAN FIND OUT

Definitive proof of a black hole would be seeing the "shadow" of an event horizon beyond which light cannot escape. With a powerful telescope, it might be possible to pick out a dim spot in the centre of the glowing accretion disc, or even gas spiralling inward and disappearing



A spinning black hole should drag local space-time with it, according to general relativity. This causes a discrepancy in the brightnesses of a double image of a "hotspot", which signifies whether the spin is that of a classical black hole. Spin may also affect the size of the disc

BLACK HOLE CONTENDERS

There are a variety of objects that might be black holes, but only further observations will tell us for sure whether any of them are

NAME	LOCATION	DISTANCE FROM EARTH	MASS (IN SOLAR MASSES)
Cygnus X-1	Constellation Cygnus	8000 light years	8.7
Sagittarius A*	Centre of the Milky Way	25,000 light years	3.7 million
LMC X-3	Large Magellanic Cloud	160,000 light years	10
M31	Centre of Andromeda galaxy	2.4 million light years	30 million
M87	Constellation Virgo	50 million light years	3 billion

1 solar mass = 1.99×10^{30} kg

electromagnetic radiation at a rate so high that they never fully form in the first place. This piqued the researchers' interest, so they tried the same calculations for cosmic black holes. They found that as a spherical shell of mass collapses inward, its gravity disrupts the quantum vacuum, giving rise to radiation similar to the quantum black hole's. It, too, leaks so much energy that the mass never gets dense enough to form a black hole with an event horizon. Instead it forms what the researchers call a "black star", which never completely swallows any surrounding matter from an external observer's point of view.

That doesn't mean the model is right, of course. "We've discussed it at lots of colloquia and seminars, and there has been lots of interest. The first reaction is incredulity; people are sceptical, but nobody's poked a hole in it yet," says Krauss. "For now I'm happy just that it's spurring debate."

The astrophysical community has been receptive but lukewarm. "When people ask me if I think black holes exist," says Broderick, "it really depends on what you mean by the term. A black hole is not just this thing inside an event horizon, it's an entire region of curved space-time. So I prefer to talk about 'black hole space-time' rather than black holes." Still, Broderick thinks it's going to be very difficult for one of these objects not to have an event horizon. "The only way to know for sure is to drop an undergraduate in and see whether his cellphone signal cuts off," he says.

In fact, there is one other serious way to probe what black holes really are. "Since they're made from warped space and time rather than of matter, the only truly convincing proof will come from radiation made from the same stuff," says Kip Thorne of the California Institute of Technology in Pasadena. He is talking about gravitational waves, also predicted by Einstein. A massive body, such as a star, warps the space-time around it. If that body is accelerating, the warping will send ripples out into space-time like a moving boat sends a wake across a pond.

The warping is so subtle that only the most violent events will create a detectable ripple – and only the most sensitive instruments will be able to detect it. That's the idea behind LIGO, the Laser Interferometric Gravity-Wave Observatory, which has stations in Louisiana and Washington state. LIGO isn't yet sensitive enough to detect even the most powerful of gravitational waves, but by 2013 its sensitivity should be 10 times finer. A space-based version of the experiment, known as LISA (Laser Interferometric Space Array), is planned for after 2015, and will be still more sensitive. The most powerful gravitational waves would come from a merger of two black holes, and this is what researchers plan to look for.

First, though, the researchers need to know what specific patterns of gravitational waves say about the collision that created them. Until recently, the calculations were so complicated that nobody knew how to do them. It was Pretorius who made the breakthrough two years ago by reworking Einstein's relativity equations (*New Scientist*, 2 June, p 34). Armed with this insight, Pretorius and others have been churning out simulations of the gravitational-wave signal from merging black holes.

Thorne and his Caltech colleagues plan to compare the frequencies of the gravitational waves with what general relativity says you should get from a classical black hole merging with another object (www.arxiv.org/abs/gr-qc/0612060). The result should say whether the black hole in question is what we think it is, or whether there is something surprising.

Of course, no gravitational waves have been detected anywhere yet, and it's not certain that they ever will be. Given the difficulty of detecting a colossal collision between two black holes, even LISA probably won't be able to detect the much fainter signal from a black hole spinning quietly on its own.

So the final answer to whether our black-hole ideas are correct may have to wait until we can send a probe to a nearby candidate and have it transmit data as it makes its final plunge. Meantime, will researchers find what they're looking for? Maybe, but it will be even more exciting if they find something else. ●

Black hole pretenders

What if the objects we think are black holes are actually something else? There are a number of alternatives that might mimic a black hole's behaviour from afar.

Neutron star: a remnant of a collapsed star, with a few times the sun's mass but the density of an atomic nucleus

Fuzzball: a construct of string theory with no singularity or sharp event horizon, but a messy surface that stores information in vibrating strings

Wormhole: a warp in space-time without an event horizon or singularity, possibly leading to another universe

Black star: a dead star in the process of gravitational collapse but requiring infinite time for an event horizon to form

Naked singularity: a point of infinite density of matter, but without an event horizon

Gravastar: a collapsed star whose space-time undergoes a phase transition that resists collapsing to a singularity

Michael D. Lemonick is a writer based in Princeton, New Jersey. His most recent book is *Echo of the Big Bang* (Princeton University Press)

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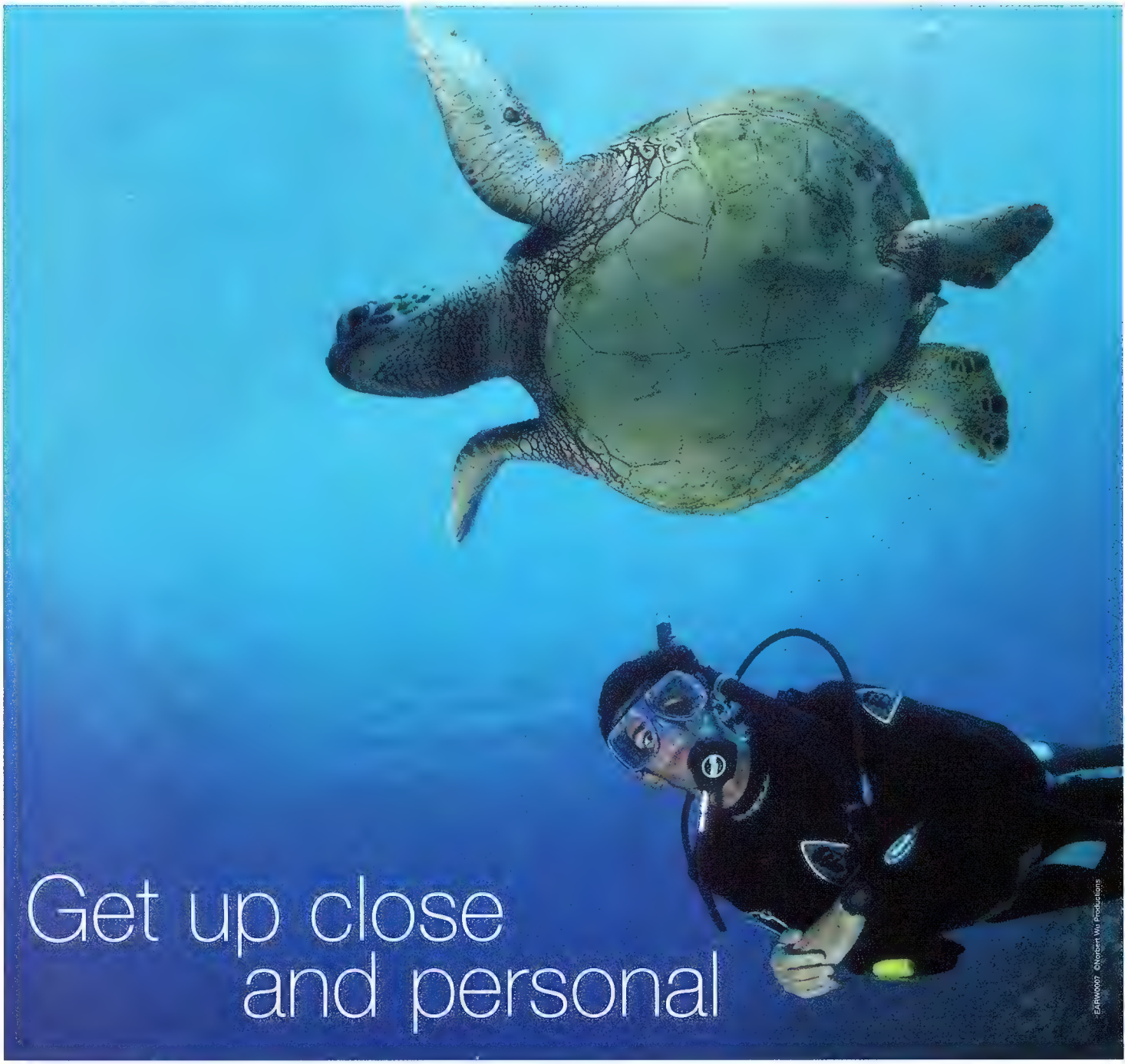

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Eureka!

Archimedes knew a lot more than we give him credit for, as **Sue Nelson** discovers

FROM ancient Syracuse, through the medieval Holy Land to Istanbul and, finally, California, it has been a long journey for a musty old prayer book. But what is written on it makes the journey worthwhile. "This is Archimedes' brain on parchment," says William Noel, curator of ancient manuscripts at the Walters Art Museum in Baltimore, Maryland. Hidden beneath the lines of ancient prayers and layers of dirt, candle wax and mould lies the oldest written account of the thoughts of the great mathematician.

This invaluable artifact is a classic example of a palimpsest: a manuscript in which the original text has been scraped off and overwritten. It was discovered more than a century ago, but only in the past eight years have scholars uncovered its secrets. Using advanced imaging techniques, they have peered behind the 13th-century prayers inscribed on its surface to reveal the text and diagrams making up seven of Archimedes' treatises. They include the only known copies of *The Method of Mechanical Theorems*, *On Floating Bodies* and fragments of *The Stomachion* in their original Greek.

As the investigation drew to a close in August, the impact of these discoveries became clear. What one of the experts described as "a very drab and dirty object" sheds fresh light on how Archimedes developed proofs and theorems, and shows that he may have employed and understood the concept of infinity more rigorously than previously thought. It also suggests that Archimedes discovered the field of mathematics called combinatorics, an important technique in modern computing. These are remarkable discoveries, yet it is only through a chain of chance events that the text was discovered at all.

The story begins in ancient Greece. Little is known about Archimedes' life other than that he was born in Syracuse, Sicily, around 287 BC, educated at Alexandria in Egypt and was the son of an astronomer. He is probably most famous for devising a way of calculating an object's density. King Hiero asked Archimedes to see if a crown was made of solid gold or, as he suspected, a mix of cheaper metals. Legend has it that Archimedes' moment of inspiration occurred in the bath. He realised that by dividing his weight by the volume of water his body displaced, he could to calculate its ▶

GEORGES STEINMETZ

Giant scans of an ancient prayer book reveal that Archimedes had infinity on his mind

MESSAGE FROM ARCHIMEDES

A long chain of chance events brought a priceless document to light which eventually revealed Archimedes' secrets

287 BC Archimedes born in Syracuse, Sicily

212 BC Killed by Roman legionary

950 Manuscript describing Archimedes' work, probably written in Constantinople

1229 Euchologion – a liturgical text of the Orthodox church – written over manuscript, creating a palimpsest

1230–1830 Euchologion used in services in monastery at St Sabas near Jerusalem

1846 Mathematical content of palimpsest identified by Constantin von Tischendorf

1906 Johan Ludvig Heiberg studies palimpsest, transcribes 177 folios and photographs 65 of them

average density. The same would work for any object, Hiero's crown included. In his excitement at solving the problem he is said to have jumped out of the bath shouting "Eureka!"

Archimedes wrote his mathematical treatises on scrolls. Though the originals are all lost, copies had been made onto papyrus and parchment. Today only three books containing Archimedes' texts remain: codices A, B and C. Of these, the first two are medieval Latin translations, held in the Vatican library. It is now known that the third, codex C, was written on parchment in Constantinople – the modern-day Turkish city of Istanbul – around AD 1000. It is the only one containing *The Method* and also contains a fragment of *The Stomachion*. Somehow, it wound up in the monastery of St Sabas near Jerusalem, where in 1229 a Christian monk unceremoniously pulled the manuscript apart, scraped the pages clean, rotated them by 90 degrees, folded them in two and wrote an orthodox prayer book called the Euchologion over it.

The prayer book lost several leaves through heavy use, but remained otherwise intact and eventually found its way to the Church of the Holy Sepulchre in Istanbul. There it lay until, in 1906, Johan Ludvig Heiberg, a professor of the history of mathematics from the University of Copenhagen in Denmark, studied the manuscript and realised the significance of the mathematical text faintly visible in the margins and beneath the prayers. He identified it as containing *The Method*, *The Stomachion* and *On Floating Bodies* alongside further works by Archimedes and other unidentified texts.

A few months later, the manuscript went missing. It resurfaced briefly when a French family living in Istanbul announced they had bought it, and there it remained, untouched for several decades. Descendants tried unsuccessfully to sell it to public institutions in Paris and London in the early 1990s, and finally, in 1998, offered the manuscript on open auction at Christie's in New York.

It sold for $2 million to an anonymous millionaire known as "Mr B". Fortunately, he turned out to be both enlightened and generous. He responded to an email from Noel asking to display the palimpsest at the Walters Art Museum. That simple request kicked off a new chapter in the saga: the Archimedes Palimpsest Project. It brought together an international team of conservators, mathematicians, imaging experts and physicists to unlock the secrets hidden within the prayer book. Mr B funded the work, spending almost as much as he had paid for the manuscript. Many involved worked for free out of the conviction that Archimedes deserved to be heard from the grave.

Among the eager scholars lining up to examine the palimpsest, one man had a head start. Nigel Wilson, a classics scholar and retired tutor at Lincoln College, Oxford, UK, had been asked to examine and describe the palimpsest for Christie's catalogue, and almost 30 years earlier he had identified a fragment from a single palimpsest folio – then held at the University of Cambridge – as containing text by Archimedes. That folio turned out to be one of the manuscript's missing pages.

Abigail Quandt, a senior conservator of rare books and manuscripts at the Walters Art Museum, took on the painstaking job of conserving and disbinding the manuscript. Wilson quickly became part of the project. "I realised at once that if you could apply even an ultraviolet lamp to the manuscript, you'd be able to read a great deal more than was read in 1907", when Heiberg was first transcribing the palimpsest.

The Heiberg translation was a constant reference point for the team. He had examined the palimpsest using only a magnifying glass, but it was in considerably better condition then than it was by the end of the century. At the time, there were 177 folios, of which three have since been lost. "In 1906, mildew had not yet begun to attack it," says Wilson. Luckily, Heiberg took several photographs of the manuscript, which were rediscovered at the Danish Royal Library

"The manuscript sold for $2 million to an anonymous billionaire known only as 'Mr B'"

THE OWNER OF THE ARCHIMEDES PALIMPSEST

Even painting over the beleaguered palimpsest could not conceal Archimedes' genius

1908–1988	1910–1915	1938	1998	1999	2000	2001–2006	2005–2006
Owned by French family	Heiberg publishes transcript of Archimedes' text	Forgeries painted on four folios	Purchased at auction by anonymous American collector	Lent by owner to Walters Art Gallery in Baltimore, Maryland	Phase I experimental imaging by teams from Rochester Institute of Technology and Johns Hopkins University	Phase II imaging by combined teams to produce pseudocolour images	X-ray fluorescence imaging at Stanford Synchotron Radiation Laboratory reveals unseen text

in Copenhagen and digitally reproduced. They filled in some of the gaps where the parchment had been eaten away by mould.

Most of the text, however, was retrieved using multispectral imaging, a technique in which wavelengths of light not visible to the human eye are beamed at the parchment and the reflected light is captured and converted by computer into a visible image. Algorithms then enhanced selected parts of the text, revealing traces of ink that are too faint to see.

Absorbing thoughts

This work was led by three imaging specialists: Roger Easton, professor of imaging at the Rochester Institute of Technology, New York; Keith Knox from Boeing in Seattle, Washington; and William Christens-Barry of Equipoise Imaging in Ellicott City, Maryland. Between them they refined the imaging technique specifically for the palimpsest by combining two different wavelengths from the red and blue parts of the spectrum. The parchment reflected both red and blue light, making it appear almost white. The pigments in the prayer ink absorbed these wavelengths and appeared black, while Archimedes' text absorbed the blue and reflected the red, appearing as a legible red script.

Yet some parts of the text remained obscure. Physicist Uwe Bergmann at the Stanford Linear Accelerator Center in California read about the problems the imaging project was having in the German magazine *Der Spiegel* and thought he might be able to help. The ink in the script contained iron, and Bergmann realised that a technique called X-ray fluorescence might reveal it. X-ray fluorescence relies on the fact that when an X-ray photon strikes an iron atom it knocks out an electron, which is immediately replaced by another electron dropping in from a higher energy state to fill the gap. This releases a photon of light with a characteristic wavelength. "We record that flash, note the position where the X-ray beam struck the page and reconstruct this in a digital image."

Even then, the task was far from straightforward, as the inks used for the prayer book also contained iron. To make matters worse, several pages had been covered with illustrations containing metals such as gold, lead and zinc, probably painted in the 1930s by forgers attempting to increase the manuscript's value. Despite these problems, Bergmann and his team managed to decode 15 pages that had failed to yield their secrets to multi-spectral imaging analysis. Of special interest were the pages within *The Method*, in which there were hints that Archimedes discussed infinity. This was a huge surprise.

It has long been accepted wisdom among historians that the ancient Greeks did not use infinity. Historian Ken Saito of Osaka Prefecture University in Japan and Reviel Netz, a professor of classics at Stanford and an expert on pre-modern mathematics, now think otherwise. Netz edited the Archimedes text and believes that the great mathematician not only knew about infinity, but was calculating with it, using an early form of calculus. "We always knew about Archimedes' role in perfecting the Greek method of dealing with infinity in a roundabout way," but now there was evidence of Archimedes talking about infinity as a kind of number, Netz says – unique in Greek thought, as far as he can tell.

Netz also proposes an intriguing explanation for the Stomachion (see Diagram) – the name given to an ancient puzzle, or "tangram", in one of Archimedes' treatises. A tangram is a puzzle in which a square is divided into different geometric shapes and, like a jigsaw, must be put back together. In the treatise the square is divided into 11 triangles, two quadrilaterals and a pentagon. Many assumed that Archimedes simply included it as a challenging game.

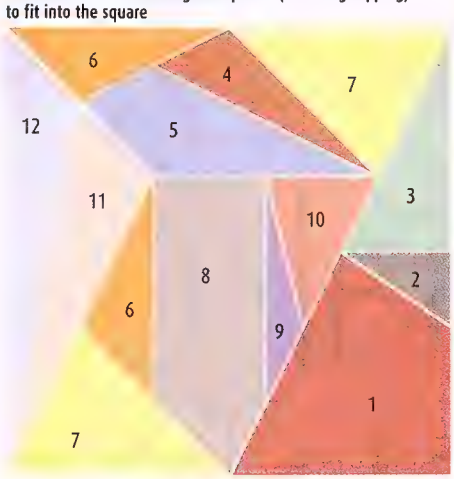
But then Netz was given a tangram by someone who had read about his work. Its shapes were ordered differently to the way he'd expected, and that sparked his own eureka moment. He realised that Archimedes might have included the Stomachion to demonstrate multiple solutions to a problem. This suggests that the question Archimedes was tackling was: "how many ways are there to complete a square, given the 14 pieces of the puzzle?", Netz says. "This would be interesting as an example of a very early study of combinatorics – the study of the number of ways in which a given problem can be solved."

Several mathematicians raced to work out the number of unique solutions, but it was Bill Cutler, a mathematician and computer scientist based in Palatine, Illinois, who produced software that came up with an answer: 536. This number was finally confirmed on paper, using a method Netz believes Archimedes would have approved of (*SCIAMVS*, vol 5, p 67).

For Noel, one of the most striking discoveries was finding the name of the 13th-century scribe whose work caused the researchers so much difficulty. Noel and Netz dedicated their book about the project to him: Ioannes Myronas. For Wilson, though, there is still important unfinished business. "I can't identify the hand of the scribe who penned the Archimedes text itself," he confesses. "I'm still looking for him. He's a wanted man." ●

THE STOMACHION

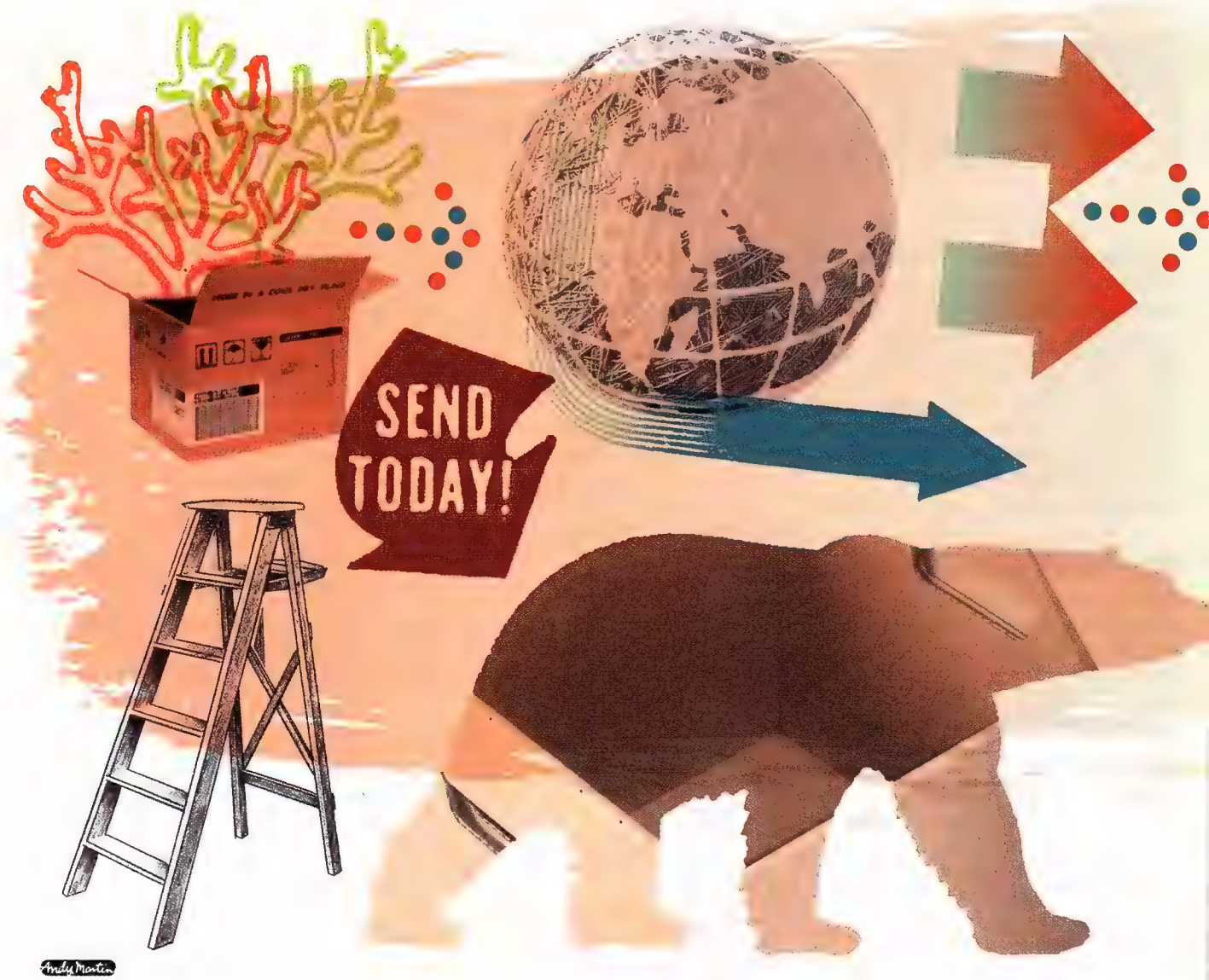
The challenge of this puzzle – discovered in ancient texts of Archimedes – is to rearrange the pieces (including flipping) to fit into the square



Here's one possible solution. There are 536 in total

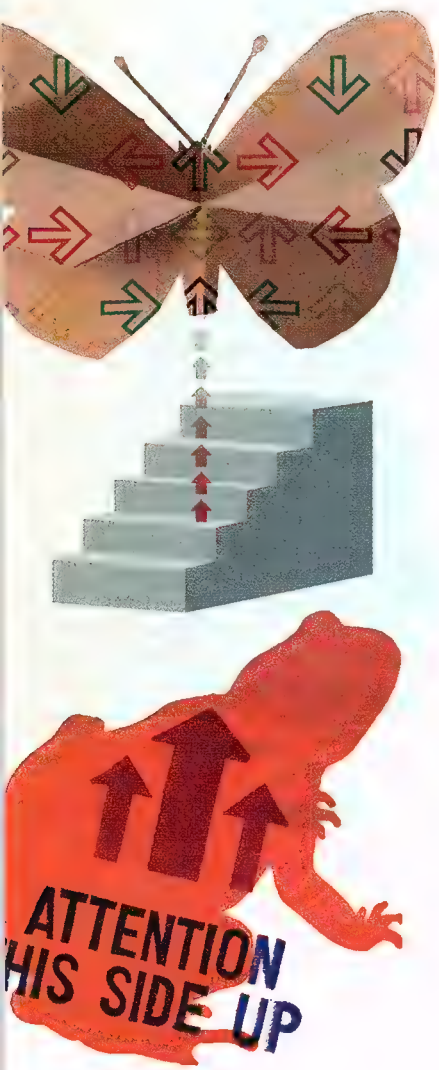
Sue Nelson is a science writer and broadcaster

Further reading: *The Archimedes Codex: Revealing the secrets of the world's greatest palimpsest* by Reviel Netz and William Noel (Weidenfeld & Nicolson, 2007)



Special deliverance

The climate is warming so rapidly that many species will become stranded. Should we FedEx them to new homes, wonders **Bob Holmes**



THE Venus flytrap is one of the plant kingdom's most notorious predators. Now, however, the trapper has become the trapped. Its home in the coastal swamps of North Carolina is changing so quickly that it cannot disperse fast enough to find suitable new places to live. It is not alone. In the coming years, many other plants and animals will face a race to keep up as global warming shifts suitable habitats to higher latitudes. Those that fall behind – perhaps a million species or more – may end up marooned and facing extinction in increasingly unsuitable environments.

It doesn't take a specialist to see one possible solution to this impending crisis, says ecologist Jason McLachlan from Notre Dame University in South Bend, Indiana, who studies the dispersal rates of trees. In fact, he hears it all the time. "Whenever I present my research, there is always somebody in the audience who says, 'Well, this isn't really a problem, because we can just move the species'." Give nature a hand and FedEx struggling species to comfortable new locations, if you will. "At first, I just dismissed the idea because it seemed sort of glib," says McLachlan, "but when you start thinking about it, you realise it will probably end up being one of the tools that we use."

As simple as it sounds, the practicalities of this so-called "assisted migration" are highly complex and could involve enormous costs, huge ecological risks and even a challenge to the very foundation of conservation biology. That is why earlier this year McLachlan, together with his Notre Dame colleague Jessica Hellmann and Mark Schwartz of the University of California, Davis, called on conservation biologists to start thinking carefully – and urgently – about the subject (*Conservation Biology*, vol 21, p 297). "It's going to be a train wreck if we wait for species to start going extinct, then panic and start moving them," he says. "We need to have the conversation now, because it will probably take a decade to reach some consensus."

The case in favour of assisted migration is straightforward: without a helping hand, many species are likely to perish as climates change. Three years ago, a team of researchers led by Chris Thomas of the University of Leeds tried to assess the number of species at risk. Using published estimates of the amount of warming that might occur by 2050, they calculated that between 38 and 52 per cent of the world's 5 to 10 million species would need to shift their geographic ranges to survive (*Nature*, vol 427, p 145). No one knows what proportion of these would be able to move quickly enough (see "Survival of the fleetest", page 48), but even optimistic estimates predict a major conservation threat.

"Anything that isn't very good at dispersing on its own is going to be in big trouble," says biologist Dov Sax from Brown University in Rhode Island. "If I had to be conservative, I would guess that would be at least 10 per cent [of all species] – which is a lot." Species living in temperate climates are likely to be at greatest risk, since climate models predict that mid-latitude habitats will shift most dramatically. "We're going to lose a lot of species if we don't move them. I think it's going to become a major strategy," Sax says.

However, knowing we may need to move some species is not the same as knowing which species to move, where to move them, and how. For one thing, the species most likely to need help are not the widespread, successful ones but the rare and marginal ones. They are often already struggling for other reasons, such as habitat loss or highly specialised ecological needs, so they may not thrive even if moved. Besides, conservationists may have a hard time convincing authorities to let them experiment with moving even small numbers of individuals from plant or animal species that are already endangered. "The US Fish and Wildlife Service is rarely thrilled about the idea of taking organisms from an endangered population," says Hellmann.

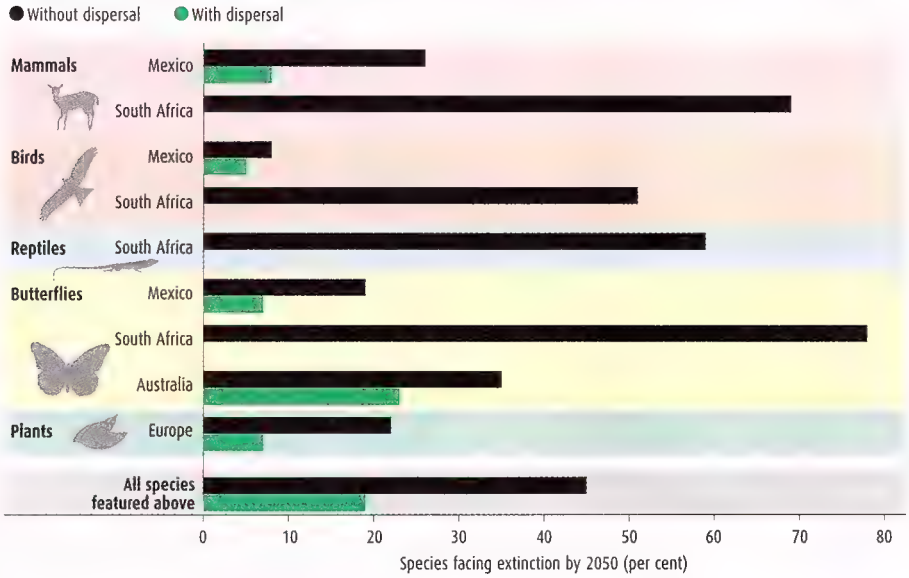
How many should you move?

What's more, moving a species is harder than it sounds – as previous efforts simply to reintroduce species into parts of their former ranges testify. "It's much more complicated than figuring out the average temperatures where a species occurs and finding another place with the same temperatures," says David Wilcove, a conservation biologist at Princeton University in New Jersey. "You have to ask what other species it is dependent on. Will those other species be at the site you want to move it to? How readily can the species be moved? How many do you want to move?" Even if the Arctic icecap vanishes altogether, for example, conservationists are unlikely to succeed in – or even attempt – to relocate polar bears to Antarctica. The task becomes harder still when populations are genetically adapted to local conditions, because if the new habitat is even slightly different they may not have the flexibility to cope with it. As a rule of thumb, ecologists figure that only 1 in 10 introductions actually result in the successful establishment of a population.

To complicate things further, climate change will not simply push existing ecosystems towards the poles. Instead, conditions are likely to change in unpredictable ways, creating climate combinations and ecosystems never ▶

IF THEY CAN'T STAND THE HEAT

As global warming forces many endemic species to relocate towards the poles, those unable to disperse fast enough will face extinction. In South Africa, many habitats will disappear altogether, leaving species nowhere to run



SOURCE: NATURE, VOL 427, P 145

seen before. For example, much of the south-eastern US is likely to end up with an entirely novel climate during the next 100 years, according to a recent analysis by John Williams and his colleagues at the University of Wisconsin (*Proceedings of the National Academy of Sciences*, vol 104, p 5738). They do not specify the form this climate might take, but other teams suggest that summers will be drier and hotter, more like the south-western US, and winters will be drier and more like those in the Caribbean. "We're moving into a novel situation. We need to ask if there is any place these species can move to in the future," says ecologist James Clark of Duke University in Durham, North Carolina.

All these uncertainties mean that anyone wanting to move a species will probably need to try repeatedly and be prepared to nurture the nascent populations for several years. "I think it's deceptive to think there are any easy answers here. The amount of monitoring and management involved in doing this right will make it expensive," says Lee Hannah, a climate change biologist at the University of California in Santa Barbara. Existing reintroduction programmes give an indication of just how expensive it will be: efforts to re-establish California condors have already cost millions of dollars, and even reintroductions of small plants can run up bills of tens of thousands of dollars.

Costs like these mean assisted migration will never be possible for more than a select few species. "I definitely see this as a secondary effort," says Malcolm Hunter, a wildlife ecologist at the University of Maine in Orono. "You could call it boutique conservation but, frankly, much of what we do at a species level is that already."

Even if the challenges inherent to assisted migration are overcome, such programmes may create conservation nightmares. There is a risk that transplanted species will become invaders that overrun their new habitats, just as rabbits and prickly pear cacti have in Australia and the kudzu vine has in the south-eastern US. This risk is relatively small, however, because invasive species tend to be robust, weed-like types characterised by nimble dispersal and rapid reproduction – the very traits that would help such species adapt to climate change without human assistance. Even so, bitter experience has shown that even ostensibly weak species can become tough customers in a new environment. Two of the world's most aggressive invaders, the Monterey pine and the Java sparrow, for example, are both highly restricted, marginal species within their native range. Biologists contemplating assisted migration will need to consider each case carefully, perhaps beginning with test introductions in areas of low ecological importance such as restored mine sites,

Survival of the fleetest

The current global warming episode is not the first race that species have had to run to keep up with a changing climate. When the ice sheets receded at the close of the last ice age, the plants and animals of North America, Europe and Asia faced the similar challenge of tracking their habitats as they shifted northward. The species alive today proved they could do it. Those that failed – such as the spruce tree *Picea critchfieldii* once widespread in eastern North America – are long gone.

In fact, analyses of fossil pollen suggest that at least some North American tree species moved northward at an average rate of about 1 kilometre per year at the end of the last glacial period. "Dispersal mechanisms are surprisingly effective," says Keith Bennett, a palaeoecologist at Queen's University Belfast, UK. Since this is similar to the rate of habitat shift projected for present-day warming, Bennett's gut feeling is that today's species should be up to the challenge.

Not everyone is so sanguine. A kilometre per year for a tree with a lifespan of a century means that by the time it dies, it must have successfully established offspring fully 100 kilometres north of itself, which stretches credulity. "Most ecologists have been extremely sceptical of those rates of spread," says Jessica Hellmann of Notre Dame University in South Bend, Indiana. Indeed, Hellmann's colleague Jason McLachlan has found genetic evidence that tree species may have ridden out the ice age in more northerly glacial refuges, giving them far less distance to travel once the climate started warming (*Ecology*, vol 86, p 2088).

Bennett counters that species are clearly capable of dispersing vast distances in a single leap. European plants and beetles quickly colonised Iceland when the glaciers had left, a feat that required them to jump hundreds of kilometres over the sea. In addition, tree species crossed the North American Great Lakes at a single bound, testifying to the effectiveness of various methods of seed dispersal, including being carried by birds, wind and water.

Even so, if climate change proceeds as rapidly as scientists fear, today's species may not have the luxury of even a few hundred years to make their poleward leaps. What's more, they are likely to find the going a lot tougher than their ancestors did 15,000 years ago. Cities and cornfields now dominate the landscape in many regions, leaving migrating species far fewer safe havens in which to land as they disperse. The race against climate change may have more losers this time than last.

MICHAEL NOLAN/SRASHDOWNDIRECT.COM

Polar bears can be moved a few kilometres, but there is not much chance of shifting them to Antarctica if the Arctic icecap melts

"Conservation ethics are rooted in a sense of place. Assisted migration asks biologists to violate that sense"

Hunter suggests. This will inevitably boost the cost and time commitments involved.

Then there are the legal implications. So far, US courts have ruled that conservationists cannot be held liable for damage caused by species such as wolves that are reintroduced into their native ranges. This is on the grounds that the species belong there, says Holly Doremus, an environmental law professor at the University of California, Davis. However, if species were moved beyond their normal range, Doremus warns, conservationists might find themselves stuck with a bill for any damage incurred.

The final hurdle facing assisted migration is a different kind of obstacle altogether – the ecological scruples of conservationists themselves. McLachlan recounts a telling chat with a fellow conservation biologist working in the Netherlands to preserve rare plants threatened by climate change. "I asked her whether she thought it would be a good thing to move those species to, say, Scandinavia, where they don't currently exist. She thought that was a good idea," he recalls. "But when I asked her if she would be equally comfortable with a Spanish ecologist moving some of his species to the Netherlands, she baulked."

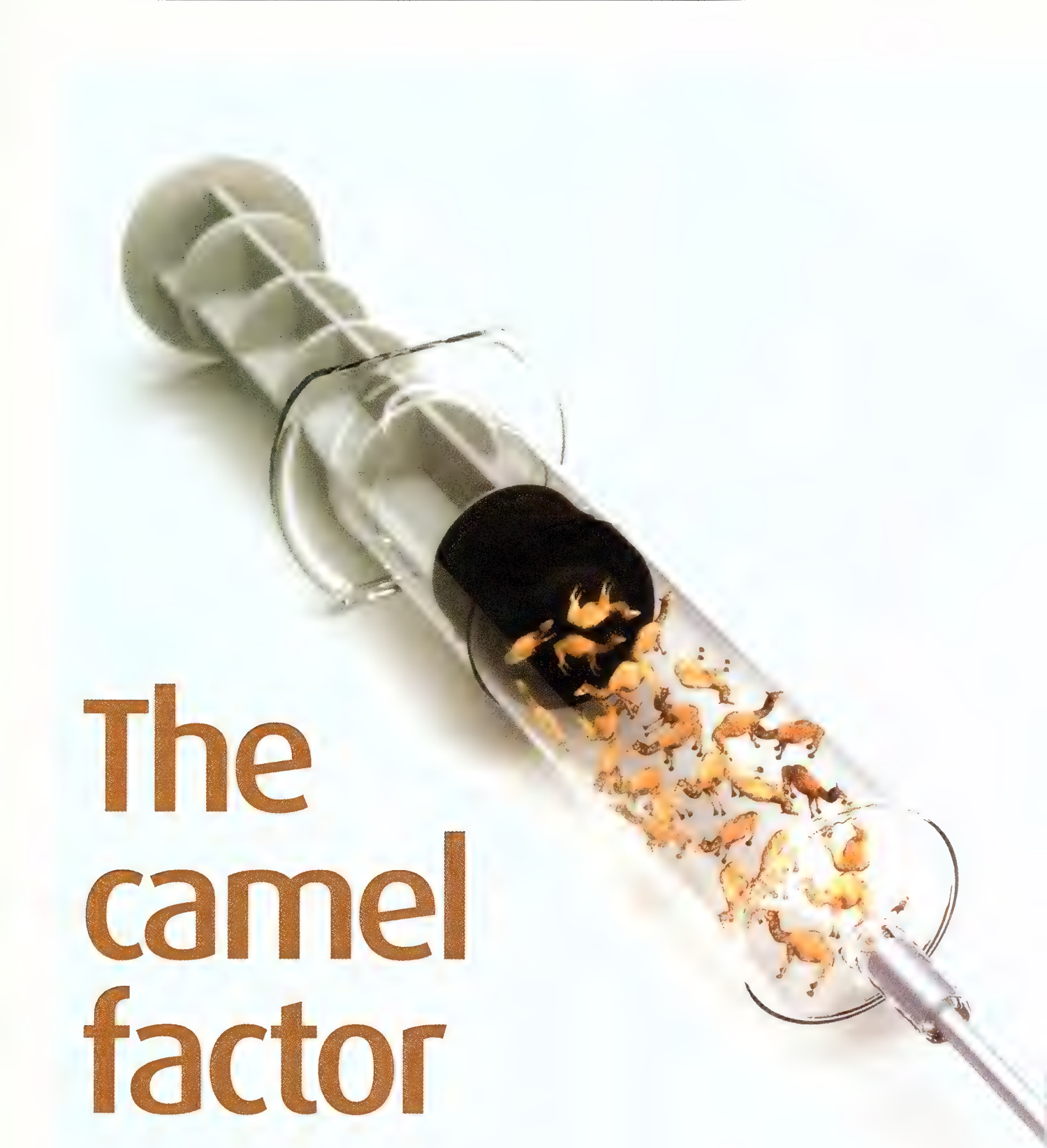
McLachlan's interpretation of that exchange is that conservation ethics are strongly rooted in a sense of place, and a feeling for what belongs where. Assisted migration asks biologists to violate that sense of place, and so is sure to encounter resistance. After all, "conservation" literally means "keeping things the same". Until now, the idea of actively creating new assemblages of species, rather than merely restoring what once was, has been anathema in conservation circles. Assisted migration has the potential to rewrite the rules in a big way.

Yet despite all these issues, most of the ecologists thinking about assisted migration believe it deserves a place in the conservationist's tool kit – if only as a last resort. "You try to conserve things in the wild first, then you work down your range of options. Assisted migration is on the list of things you need to consider," says Hannah. "To me it falls into the category of intensively managing species at risk." For Richard Primack, a plant ecologist at Boston University, the case is even clearer. "The alternative to moving species is just to watch them go extinct," he says.

In the conservation trenches, things have yet to get so desperate. "Assisted migration is not a major part of our plans right now," says Patrick Gonzalez from The Nature Conservancy (TNC), a conservation group based in Arlington, Virginia. "We are developing and testing a suite of adaptation strategies to help ecosystems adapt to warmer temperatures." These include protecting habitat corridors to give species a better chance to shift to higher latitudes on their own – a much less labour-intensive option, if it works.

Gonzalez and his colleagues are also exploring ways to manage existing habitats to minimise the effects of climate change. In areas that are becoming drier, for example, TNC is encouraging the growth of more heat-resistant varieties of native plants and performing controlled burns more frequently to reduce the risk of catastrophic bush fires. They are also trying to identify sites that may be naturally less vulnerable to climate change – northern slopes of mountain ranges, for example, and habitats near large lakes that can buffer temperature changes. Such refuges may offer species a place to survive climate change without needing to migrate too far.

The most effective tool in helping species adapt to climate change, however, is one that is already on everyone's agenda: slow down the rate of global warming. After all, if species have a century instead of 50 years to move a given distance, more of them are likely to survive the journey. "Every bit we can do to slow down climate change really helps," says McLachlan. ●



The camel factor

A unique ingredient in the blood of camels and their relatives could help treat everything from dandruff to cancer. **Henry Nicholls** reports

IT IS not a problem university lecturers face all that often. In the 1980s, Raymond Hamers was confronted by a couple of bold undergraduates complaining that the practical experiments for their course were boring and predictable. Could he find them something more original to investigate?

Hamers, an immunologist then at the Free University of Brussels (VUB) in Belgium, remembered that he had half a litre of camel blood sitting in a freezer. Although it was earmarked for research into sleeping sickness, he figured he could spare a little for the students. "Why don't we see if we can purify camel antibodies?" he asked them.

The results flummoxed everyone. "We couldn't believe it," Hamers says. The pattern of antibodies extracted from the blood suggested that, in addition to the standard type found in all vertebrates, the camel produced an entirely novel, simpler variety.

What started out as a student project soon turned into a major line of research for Hamers and his colleagues. At first they assumed the smaller proteins were merely fragments of conventional antibodies. But fresh camel blood flown in from Kenya contained the same novel antibodies. "We spent two years checking whether we were right because it was so blooming crazy," says Hammers.

The team went on to demonstrate that the new kind of antibody is found not only in the dromedary camel but also in other camelids – the Bactrian camel, llama, alpaca, guanaco and vicuña (*Nature*, vol 363, p 446). Why camelids evolved this unique type of antibody in addition to the normal kind is still a mystery, says Serge Muyldermans, a member of the original team who is now at the Flemish Institute of Biotechnology. Unpublished experiments indicate that camels facing a range of different challenges to their immune systems do not favour one type over the other, he says.

However they evolved, the antibodies are far more than an immunological curiosity. From the start, Hamers knew he was onto something special. While normal antibodies have huge medical potential, the sheer size of these bulky proteins is a problem for all sorts of reasons, which is why many teams have been trying to create smaller versions.

What makes camel antibodies so special is not that they are somewhat smaller than conventional antibodies, but that their key component – the variable portion that binds to other proteins – works fine all by itself. That means you can produce even smaller proteins, dubbed nanobodies by Muyldermans, that can do almost everything normal antibodies do – and some things they cannot – yet are just a tenth of their size.

Nearly two decades after that student project, the results of the first trial of a nanobody-based therapy are due out soon. And before long we could be hearing much more about them thanks to their many advantages. Nanobodies can get to parts of the body and parts of molecules that conventional antibodies cannot. They can also be attached to a toxin or other molecules without the whole creation becoming impossibly large.

"We couldn't believe it. We spent two years checking whether we were right because it was so blooming crazy"

That's not all. Nanobodies are tougher than normal antibodies and could be swallowed to treat gut diseases without being digested, for instance. They are so much easier and cheaper to make that it might be feasible to add them to consumer products, such as anti-dandruff shampoos. They can be engineered into plants and animals to produce all sorts of effects, from revealing the inner workings of cells to altering metabolism. They might even be the ideal tool for creating miniature chemical laboratories.

Normal antibodies consist of Y-shaped proteins in which the structure of the tail stays constant while the tips of the arms vary greatly, allowing different antibodies to bind to different targets. If a new virus invades our bodies, for instance, within days our immune systems can generate antibodies that bind specifically to that virus and help destroy it.

Back in the mid-1970s, when scientists first worked out how to manufacture antibodies to order, there was great excitement. They seemed to have endless potential as therapies for everything from infectious diseases to cancer. Conventional drugs consist of a huge variety of small molecules that can have all sorts of unexpected side effects. With antibodies, there is much less concern about toxicity, as our bodies produce them already. Their size can be an issue, though. For instance, they are too large to be absorbed into the blood from the gut and thus have to be injected rather than swallowed.

Despite all the initial excitement, producing human-like antibodies that our immune system will accept proved to be rather tricky. Only now, decades later, are antibodies really starting to deliver on their promise, with around 20 on the market and hundreds more in the pipeline.

Even so, creating and manufacturing new therapeutic antibodies remains a challenging and expensive process, not least because the molecules' size and complexity mean they can only be produced by mammalian cells. Hence the demand for smaller proteins that act like antibodies.

The simplest approach is to strip down normal antibodies. These consist of two heavy chains and two light chains, but only the ends of the chains contain the variable regions that bind to other proteins (see Diagram, page 53). So why not chop off the variable regions, or domains, and use ▶

PETER CROWTHER

Camels' unusual immune system points the way to revolutionary new drugs

these as "single-domain antibodies"?

This is just what Gregory Winter of the UK Medical Research Council's Laboratory of Molecular Biology in Cambridge did in the late 1980s. But his team ran into a serious obstacle. Since the heavy chain of human antibodies is usually bound to a light chain, the proteins that form human single-domain antibodies are naturally sticky, and have a tendency to clump together and to bind to proteins other than the target, making them useless. "We had to overcome this and find ways of giving them good biological properties," says Winter.

While Winter works on solving the issues with human single-domain antibodies – several drugs based on them are being developed and the company he co-founded was bought by GlaxoSmithKline earlier this year – other groups are using larger fragments of antibodies to avoid the stickiness problem. What makes the streamlined camelid antibodies so special, however, is that there is no stickiness problem with the single-domain antibodies – nanobodies – derived from them. This is because they lack light chains altogether, so the variable domain at the end of the heavy chain has evolved to work in isolation, rather than to stick to an adjoining light chain.

So creating nanobodies is relatively easy. The first step is to inject camels or llamas with whatever it is you want the nanobody to bind to – a virus, say. A few days later you take some blood and identify the white blood cells that are making antibodies that bind to the target, then extract the DNA that codes for the variable domain.

For many purposes, this is all that's needed. Nanobodies intended for injection into the human bloodstream may require some tweaking to ensure they do not appear foreign and hence provoke an immune reaction, but they are already very similar to the variable domain of human antibodies.

The big advantage of single-domain antibodies is that these proteins are simple enough to fold correctly when they are made in genetically engineered bacteria or yeast. These methods of production are so much cheaper than using mammalian cells that nanobodies could be used in a host of ways unthinkable for normal antibodies, such as in anti-dandruff shampoos.

Nanobodies are also pretty tough, partly thanks to extra internal bonds that reinforce their structure. "You can use them in very harsh conditions where normal antibodies collapse, get digested or don't fold," says Muyldermans. That not only makes them easier to store and transport than conventional antibodies, it means some nanobodies can survive a journey through the gut, raising the prospect of nanobody pills for treating gut disorders such as inflammatory bowel disease or colon cancer.

Another is diarrhoea caused by rotavirus, a major killer of children in developing countries for which the only current treatment is rehydration. Nanobodies that bind to rotaviruses have been shown to cut the death rate in mice. Children could be dosed with live bacteria that churn out these nanobodies, making the treatment cheap.

There's more. Nanobodies open up a wealth of targets that larger antibodies cannot

Shark attack

Camels and their relatives are not the only vertebrates with an unusual, streamlined kind of antibody. In 1995, nurse sharks were found to sport similarly slender antibodies for targeting invading viruses and bacteria.

A few years later, Stewart Nuttall, a microbiologist at CSIRO Health Sciences and Nutrition in Melbourne, Australia, decided to see how widespread the phenomenon is. His team started by collecting blood samples from the spotted wobbegong (pictured left), a flattish, bottom-dwelling shark that can grow to over 3 metres long. They too had unusual antibodies similar to those in camelids (*Molecular Immunology*, vol 38, p 313).

It now looks as though all sharks have them. "These antibodies are present in every shark species that we have tested, though for obvious reasons we haven't gone near great whites," says Nuttall. "Genome sequencing initiatives suggest that the antibodies may also be present in rays."

This suggests that sharks evolved these unusual antibodies soon after they diverged from other vertebrates more than 400 million years ago. The similarity between the antibodies in sharks and camels is almost certainly an example of convergent evolution, with natural selection arriving at the same solution on separate occasions.

Small proteins derived from shark antibodies are already being developed for various purposes: for example, to use in sensors designed to detect cholera. Technically known as "shark new antigen receptor variable domains", they should of course be called sharkbodies.

reach. They are small enough to wheedle their way into the active sites of enzymes, deep clefts in receptors on the surface of viruses and bacteria, or into the heart of dense tumours. It looks as if they might even penetrate the blood-brain barrier effectively enough for drug designers to think about adapting them to treat conditions like Alzheimer's disease.

The small size of nanobodies and other single-domain antibodies does have one big disadvantage, though: "In practice, these things get pissed out very fast, usually too fast to be of any therapeutic use," says Winter. This means nanobodies last just hours in the bloodstream compared with up to three weeks for conventional antibodies.

The answer is to make them bigger by linking them to other molecules. While this can sacrifice some of their unique advantages, these hybrid proteins are often exactly what's needed. Combining two identical nanobodies can make them bind more tightly to a target, for instance. Alternatively, two different nanobodies can be combined to create a protein capable of bringing together the target and a killer cell from the patient's immune system (the same function is carried out by the "tail" of full-sized antibodies).

For cancer treatments, a nanobody can be linked to an "effector molecule" that kills cells, such as a toxin, an enzyme or a radioactive substance. In 2004, Muyldermans's team created a nanobody that binds to the surface of many tumour cells. They then engineered bacteria to produce the nanobody linked to an enzyme called lactamase, which converts a harmless prodrug into a potent killer of cells.

The idea was that the nanobody part would hold the enzyme close to the surface of the cancer cells (*Cancer Research*, vol 64, p 2853). "It was incredibly effective in animals," says Muyldermans.

For now, though, the company set up by the VUB in 2002 to develop nanobody-based healthcare products – Ablynx – is focusing on other projects. The most advanced is an anti-clotting drug known as ALX-0081.

While there are already drugs on the market designed to reduce the likelihood of clotting in patients at risk of heart attacks or strokes, many interfere with the clotting process everywhere in the body, which can result in bleeding. ALX-0081, however, consists of two linked nanobodies that bind to a protein called von Willebrand factor, which is only involved in clotting where the blood is moving fast. This means it should keep fast-flowing blood in arteries free of dangerous clots without affecting clotting elsewhere.

The signs are that ALX-0081 is going to breeze through its first trial, which began in March. Early results from healthy volunteers suggest that it produces the desired effect without causing any serious side-effects, says Edwin Moses, head of Ablynx. The full results should be released before the year is out.

Inside the brain

Ablynx is developing several other nanobody-based drugs, including one for rheumatoid arthritis and another designed to home in on a target inside the brains of people with Alzheimer's. But there are plenty of other exciting ways in which these proteins could be put to good use, says Hamers: "The applications are endless."

Before he retired a decade ago, Hamers explored the possibility of using nanobodies to study neural development. His idea was to genetically engineer organisms so they produced nanobodies inside their cells. "Intrabodies" that targeted and inhibited specific proteins would reveal the role of these proteins in laying down the nervous system.

This has now become a reality. "We can now express antibodies stably inside the cell to block or choke any protein," says Siyaram Pandey, a biochemist at the University of Windsor, Ontario, in Canada. Another group has shown that fluorescent nanobodies – dubbed chromabodies – can be used to light up specific proteins inside living cells (*Nature Methods*, vol 3, p 887).

The applications of intrabodies are not limited to research. Since nanobodies are far simpler than full-blown conventional antibodies, they can also be engineered into plants. Nanobodies that target specific enzymes have been shown to alter metabolic pathways in potatoes (*Nature Biotechnology*, vol 21, p 77). This approach might also make it possible to endow crops with immunity to specific pests or to create vegetables that combat gut infections when eaten.

Hamers's vision does not end there. Nanobodies that bind to different parts of a surface – on a crystal lattice, say – could be used to align different enzymes into a carefully coordinated sequence. "This would be like creating a miniature chemistry laboratory capable of performing a series of incredibly efficient reactions," he says.

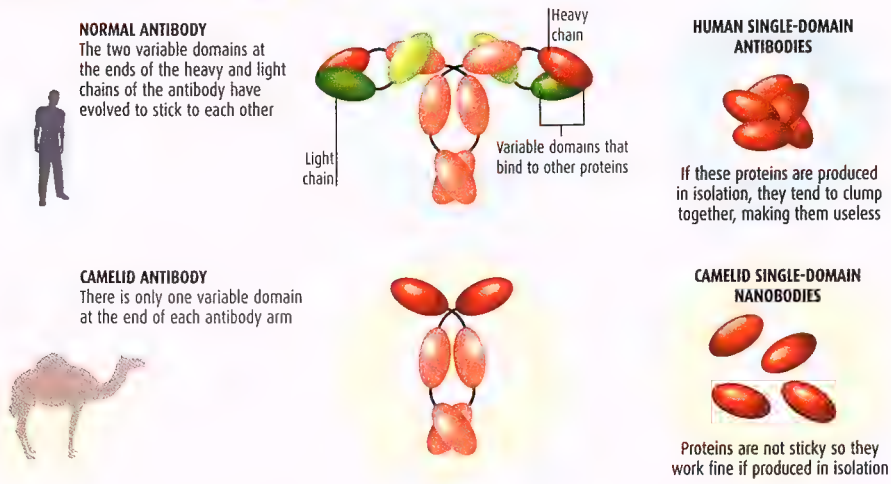
For now, this is a futuristic vision. But who knows? If nanobodies and other single-domain antibodies realise their promise, one day we could find these talented little proteins are everywhere. ●

Henry Nicholls is a science writer based in London, and author of *Lonesome George: The life and loves of a conservation icon (Palgrave Macmillan, 2006)*

THINKING SMALL

Single-domain antibodies should be potent drugs, but making them from human antibodies poses problems

Heavy chain Light chain



Photography: Pål Hansen

Dressed for life

The famously fickle fashion industry wastes resources like there's no tomorrow, a point that is not lost on fashion designer **Rebecca Earley**, who has embraced the green movement by creating clothes that are less wasteful. She told **Lucy Middleton** that it's high time other designers developed a more responsible attitude to the world's resources

By "upcycling" clothes Rebecca Earley can modify an old shirt and resell it as a designer item

What's wrong with "normal" clothing?
The vast amounts of water, energy and toxic chemicals that are used in their production. Take cotton. Everyone thinks it's the good guy. Yet cotton cultivation accounts for around 10 per cent of all pesticides and 20 per cent of all insecticides used in agriculture. And it's not just the manufacture of clothing that's environmentally unfriendly; it's the upkeep and disposal of clothes too.

What's the problem with pesticides?
There's an incident that sticks in my mind in which a farmer in Nallou, Benin, went home to his family one evening in August 2000 having treated his cotton field with the pesticide endosulfan. Before going in, he put his clothes on the roof of his tin house, out of reach of his young children. During the night it rained and the chemicals in his clothes were washed into the family water butt. The next morning all four children drank from the butt and died.

Cotton farmers experience everything from rashes and blindness to death. The pesticides they use are believed to cause between 20,000 and 40,000 deaths each year, mostly as a result of accidental poisoning and mostly in rural communities in developing countries. The Pesticides Action Network UK has documented 67 deaths in one cotton-growing region of Benin in a single growing season. Many farmers can't read the precautions and don't wear protective clothing. They get completely covered in these chemicals. That's why we campaign for organic cotton that is grown without pesticides.

How does cotton farming affect water resources?
Cotton farming is incredibly water intensive. It's needed not only for growing but for processing and dyeing. So much water is needed that it's often diverted away from communities. There's a photograph that is part of the Earth from the Air series by Yann Arthus Bertrand of a ship stranded in what used to be the Aral Sea between Uzbekistan and Kazakhstan. The Aral Sea has lost three-quarters of its water as a result of the Soviet Union diverting rivers to help irrigate cotton farms in central Asia. Nearly 60,000 fishermen are thought to have lost their livelihoods when the fish disappeared along with the water.

What about washing cotton clothes?
Laundering is energy consuming and accounts for 85 per cent of the energy requirement of a garment. Cotton requires way more energy than say polyester because it is washed at higher temperatures, takes longer to dry and needs ironing. We think of it as cheap and natural but it is neither.

How did you become interested in eco-fashion?
There is something so transient about producing fashion clothes. I couldn't bear the idea that I was putting so much time and effort into something that would be gone in just a few months. I suppose it was a vanity thing. You just want your work to be valued for longer. It was that thought that led me to ask

Profile

Rebecca Earley is associate director of the Textile Futures Research Group based at the Chelsea College of Art and Design in London, where she investigates new techniques and theoretical approaches to environmentally friendly textile design. The focus of her research is the reuse and recycling of fabrics and the reduction of chemicals and waste in small production runs. She graduated from Central St Martins College of Art and Design in London in 1994 with an award-winning "heat photogram" printing technique that produces printed textiles without polluting water and with minimal use of chemicals. Her work forms part of an exhibition called Ever & Again: Experimental Recycled Textiles, which runs at the Triangle Gallery in London from 19 to 25 October.

how I can make things that last longer.

Being green is not in the psyche of average clothes designers at all. They'll avoid thinking green if they can because they think it will restrict their design. Ultimately designers are egotistical creatures. They want to be creative and why not? That's what the whole discipline is about.

But what we are doing here at Chelsea is teaching students how to incorporate environmental thinking into design.

In 1997, 7 per cent of the year group were interested in green issues, and now it's more like 68 per cent. But I still don't think there are enough designers out there designing good things that are reasonably priced, trendy, attractive and durable.

How does your work help?

I investigate the role the designer can play in reducing the environmental impact of a garment. It's about the materials that go into the product, how long the product will last, how it will be used and washed, how it will be disposed of, and so on.

What strategies do you use for minimising the environmental impact of a garment?

There are many – some well known. We can use organic materials; we can reduce the air miles needed to transport the product; and we can consider "emotionally durable" design – making products that people want to keep. We can also give garments lots of different lives. For example, by cutting and mounting a polyester shirt, it might become a picture hanging on the wall. Or by melting and remodelling the polyester, it could become a necklace. You can also restrict your colours – turquoise is absolutely out because using it releases copper compounds into the environment. As are fluorescent colours.

We also consider "upcycling", which involves taking used materials and increasing their value. For example, by taking an old shirt that someone won't wear just because they've

> "I have a fleece made from recycled Evian water bottles"

dropped a tiny bit of balsamic vinegar on it, printing over the top of it and perhaps cutting into it to make it fit with current trends. It's very quick and easy. I can upcycle a worn-out ordinary shirt into a designer handprinted B.Earley one. We believe that through this kind of recycling we can improve and produce very high-end products that are fashionable and desirable.

How can you reduce the amount of washing a garment requires?

By designing clothes that don't have to be washed as often. That can mean anything from printing or embellishing the areas that are likely to stain – for example the cuff or the chest – to designing lower arm holes and low-cut fronts to avoid food or sweat stains.

Why is polyester interesting for eco-designers?

Polyester is a valuable plastic that is 100 per cent recyclable and yet it regularly ends up in landfills. It's crazy. Bottles can be made into shirts and the shirts can be shredded, melted, extruded and woven again. For example, I have a fleece made from recycled Evian water bottles. You don't lose any quality, so you can recycle it over and over again. It's got lots of potential and that's really exciting. It's also very malleable and interesting in terms of the engineering technologies you can use with it – you can laser cut it, sonic weld it, heat treat it and mould it. From a textile point of view it's phenomenal. But plastic is so cheap it's difficult to make any profit from recycling.

What does the future hold for green clothes?

People are getting more interested. It's funny because we've been doing this for around 12 years and only now is it just beginning to take off. The past 18 months have seen a very steep rise in awareness, interest and demand for eco-fashion. Green is so the new black. ●

HEIDI BRANDENBURG

CHANGE IN A TIMELESS LAND

What does a future of climate change have in store for the Arctic, asks **Angela Self** in this winning entry in the 2007 New Scientist/Wellcome Trust essay competition

THE Arctic wind blasts across the frozen lake in Russia's polar Urals region, where I'm waiting anxiously with the rest of the research team. There is no sign of the helicopter yet. "What time are they due?" I shout into the blizzard. Four o'clock – only a few minutes to wait. Our field equipment is slowly disappearing under a blanket of snow. We kick it clear: when our flight to warmth and safety arrives, we have to be ready.

If there is one place you might think would welcome global warming it would be here. Yet local people will tell you that this year's relatively mild weather has caused them many problems. Usually the rivers and lakes are frozen for nine months of the year, allowing people to travel safely over them until June. But this year the river ice melted early. Just a week ago, in April, a vehicle plunged through the ice into a nearby river.

Things could be worse still for the reindeer and the indigenous Nenets whose whole livelihoods depend on them. The herds must cross the ice at the end of every winter on their annual migration to their summer pastures in the north. With the ice gone, will the reindeer swim the swollen rivers, or will they stay in the southern zone? Staying put could be disastrous: as the surface layer of permafrost melts, the tundra becomes an impenetrable mire of thick, clawing mud that even reindeer cannot cross. Unable to migrate to frozen land in the north, they could become trapped on islands of degrading land in a quagmire sea.

This seemingly timeless environment is changing, and we're here to find out how. We aim to collect cores from the muddy lake sediment. The sediment cores are a 2-metre-thick sandwich of organic matter, mud and eroded rock, but preserved in these layers is a sequential record of the organisms that have lived in and around the lake. By examining the organisms in each layer we can see how the biodiversity, productivity and characteristics of the environment have changed over time. My own interests lie in the minute head capsules of chironomid larvae. These tiny, non-biting flies are easily overlooked in the haze of insects that swarm over Arctic lakes in summertime, but they are useful indicators of past climate. Each species has its own specific range of ecological conditions that it can tolerate – particular temperatures or nutrient requirements. Fluctuations in the various species over time enables me to estimate past temperatures and environmental conditions.

Cores I collected last year in western Siberia showed a rapid increase in abundance and

> "The lake, land and sky are merging in a kaleidoscope of snow"

biodiversity of chironomid larvae in the late 20th century. These results are echoed in other studies from the Arctic Circle. These biotic changes are profound and consistent, but the underlying mechanisms for change are less clear. Are the organisms responding directly to temperature, or indirectly through changing environmental parameters such as earlier ice melting, a longer growing season or increased nutrient flow? By examining different aspects of the vegetation, aquatic fauna and sediments of this lake, our team hopes to elucidate the root causes. We could then start to predict how these unique environments might respond to climate change in the future and identify particularly vulnerable habitats.

Until recently, the Nenet people could walk their reindeer over the frozen river

The helicopter is now 40 minutes late. Around us the lake, land and sky are gradually merging in a kaleidoscope of snow. In 5 minutes we'll have to start digging a snow hole. Our remoteness and vulnerability have never felt more apparent. Then suddenly above the howl of the wind comes the drone of rotor blades.

It is an immense relief to know we are safe, but we are leaving with the realisation that for the Arctic and its people the future is uncertain. What makes it all the more sobering is that their livelihoods depend on action by people who are remote, spiritually and physically, from this extreme environment – action that so far has been slow in coming. ●

Angela Self is a PhD student at the Environmental Change Research Centre in the Department of Geography at University College London

The Stuff of Thought by Steven Pinker, Viking, ISBN 9780670063277

STAND UP FOR THE WET NOODLE

Steven Pinker claims that without concepts hard-wired into our brains, language would be as useful as a "wet noodle". That ignores evidence to the contrary, says **Philip Lieberman**

THE opening pages of *The Stuff of Thought* present the same arguments on the nature of language as Steven Pinker's earlier book, *The Language Instinct*. Language and grammar, Pinker says, are hard-wired into our brains. He presents the Chomskian notion that "children must be equipped with an innate universal grammar; a set of plans for the grammatical machinery that powers all human languages".

According to Pinker and Noam Chomsky's adherents, children do not learn the particular syntactic processes that characterise the grammar of their native language. Instead, the rules of syntax for every language on Earth lie dormant in their brains. The details of syntax are software that has been preloaded into our brain's hard drive by evolution.

Now *The Stuff of Thought* extends the software licence from syntax to words themselves. According to Pinker, we don't learn the meanings of particular words, but instead have a store of innate "primal concepts" that are activated when we hear a word. These concepts – such as *cause*, *motion*, *space* and *time* – comprise the elementary building blocks of language and thought. Presumably, when a child sees her mother point to a dog and hears her say "dog", innate primal concepts like *animate*, *animal*, *safe* and perhaps *edible* are activated. Innate concepts, says Pinker, give language its power. "If meanings could be freely reinterpreted in context, language would be a wet noodle and not up to the job of forcing new ideas into the minds of listeners."

Certainly there are limits to the range of meanings a word can take, but to me it seems clear that we actually learn the meanings of most words through experience, or through secondary sources such as books, film and television. Everyday words like fire, table or dog have multiple meanings, and the same words can mean different things to different folks. A short session with the *Oxford English Dictionary* confirms that a word's meaning can change over time.

The 10-tonne gorillas missing from *The Stuff of Thought* are neurophysiological studies showing how the brain deals with words and their meanings. Studies such as those reported by Alex Martin and Linda Chao (*Current Opinion in Neurobiology*, vol 11, p 194) show that a word activates the same areas of the brain that are involved in perceiving the thing to which the word refers, as well as pertinent motor areas. These findings point to "fuzzy" representations of a word's meaning acquired through life's experiences, rather than hypothetical innate primal concepts.

Ultimately, Pinker neglects the single biological truth that rules out innate detailed knowledge of language: genetic variation. If Pinker's hard-wired elementary concepts actually existed, genetic variation would ensure that some people lacked a concept or two. We would encounter people who could not acquire the meanings of entire sets of words or think or act upon these concepts. A child missing the gene coding for the primal concept *kinship* would never be able to understand words such as family, cousin, mother and so on. Certainly humans possess an innate capacity to acquire language, but as I pointed out in my 1984 book *The Biology and Evolution of Language*, genetic variation rules out theories that posit innate knowledge of language's details.

Pinker's discussion of the linguistic analysis of verbs and its relation to meaning is a lucid introduction to formal semantic theory. Jokes and rambling commentaries on topics from Kant to swearing provide breathing space for readers overloaded with the minutiae of theoretical linguistics. But readers who wish to learn more about current research on the manner in which language influences the way we think and act will have to continue their search. ●

> "Genetic variation rules out Pinker and Chomsky's theories"

Philip Lieberman is the Fred M. Seed Professor of Cognitive and Linguistic Sciences at Brown University in Providence, Rhode Island

CLAUDINE DOURYAGENCE VU

We are born with a store of concepts, such as *cause*, *time* and *kinship*, Pinker says

Set free to kill again

TONY BRAIN/SPL

DDT is back. For more than three decades, the most effective chemical against malarial mosquitoes was virtually banned around the world. The ban, triggered by environmental concerns, torpedoed a campaign begun in the late 1950s to eradicate malaria from the planet. Since then, the disease has returned with a vengeance, killing more than 2 million people a year. Late last year, the World Health Organization took a U-turn and announced that DDT will once again be one of its main tools against malaria. So was the ban a ghastly mistake? Did the world throw away the chance to eliminate a disease that kills almost as many people as AIDS? And if so, should we blame environmentalists?

IN 1956, American scientists came up with a plan to wipe malaria from the face of the Earth using the pesticide DDT. US troops had sprayed it widely during their jungle operations in the second world war, and the chemical had eliminated the last pockets of malaria in the US and Europe. Prompted by Paul Russell of Harvard School of Public Health, the State Department declared that within five years American science could do the same for the rest of the world.

Congress allocated more than half a billion dollars for the task, and by 1958 thousands of drums of DDT were on their way to Latin America, Africa and tropical Asia. Scientists saw mosquitoes as easy targets. The insects passed on malarial parasites while gorging on human blood as their victims slept. Afterwards, they settled on bedroom walls to digest the blood. Spraying those walls with DDT every six months had been shown to repel or kill most of them.

Confident that the disease would soon be eradicated, Harvard stopped teaching its students about malaria. Early results were impressive enough to warrant such optimism. In India, where spray teams doused hundreds of thousands of villages, by 1961 hospital admissions for malaria had fallen by 90 per cent, and global death rates had fallen by around 95 per cent.

Donald Roberts, who is now a medical entomologist at the Uniformed Services University of the Health Sciences in Bethesda, Maryland, took part in early eradication programmes in Brazil. "Almost miraculous results were achieved," he says. "We quickly eradicated malaria from southern areas where most people live." Even in the Amazon basin its incidence was much reduced.

But then the funds began to dry up. Congress had voted for a five-year programme and in 1963, oblivious to calls for one more heave, it pulled the plug. Many tropical countries, including Brazil, carried on spraying, but the global eradication drive ground to a halt.

In any case, western enthusiasm for the enterprise had evaporated. The previous year had seen the publication of the book that started the modern environment movement. *Silent Spring* by Rachel Carson of the Woods Hole Marine Biological Laboratory in Massachusetts called for the banishment of pesticides in general and DDT in particular. It was killing wildlife and making people sick, Carson said. In fact, her attack was aimed at farmers who sprayed DDT on their fields, but the distinction between that and spraying relatively small amounts inside houses was lost. In 1968, the journal *Science* published a clutch of articles that seemed to confirm that DDT was damaging the environment, and the following year rich countries and their aid agencies started imposing bans.

Supposedly less harmful pesticides were tried, but nothing worked against mosquitoes as well as DDT. A decade later, with the disease creeping back to its old haunts, the WHO switched from fighting the mosquito to fighting the malaria parasite with drugs, and backed efforts to find a vaccine.

WALTER SANDERS/TIME LIFE

Widespread spraying of DDT in the 1950s led to a dramatic reduction in the incidence of malaria

Meanwhile, environmentalists were as determined to ban DDT as doctors had once been to banish malaria. In 2001, the pesticide appeared on a list of 12 toxic industrial chemicals that were to be banned worldwide under the Stockholm Convention on Persistent Organic Pollutants. Then the backlash began.

More people were being killed by malaria than ever before. Old hands like Roberts, who had witnessed the early success of DDT, eventually persuaded the negotiators who had drafted the convention to allow DDT's continued use for public health.

In 2006, the WHO – which for much of the previous decade had been headed by the environmentalist Gro Harlem Brundtland – made a dramatic U-turn and began encouraging the use of DDT again. Announcing the change, Arata Kochi, director of the WHO's new Global Malaria Programme, said: "Of the dozen insecticides WHO has approved as safe for house spraying, the most effective is DDT." Sprayed indoors, he said, it "poses no harm to wildlife". Fifty years after the launch of the first global campaign to eradicate malaria, DDT was back.

Roberts blames this debacle on the "well-funded advocacy and all-consuming political and economic power of the environmental movement" pitted against the "weak political willpower of the public health establishment".

Environmentalists are unrepentant. The WWF says the insecticide should be "phased out and ultimately banned". But its benefits are hard to dismiss. Virtually all countries that had a high incidence of malaria half a century ago saw a dramatic decline when they used DDT. When spraying stopped, the incidence rose again. Perhaps the best-documented recent case is South Africa, where DDT was banned in the mid-1990s. Malaria then increased tenfold, and since spraying resumed in 2001, rates have begun to fall again.

Meanwhile, many of the fears over human health raised by Carson and the *Science* papers of 1968 have not been realised. Carson suggested that DDT could cause liver and breast cancer, but there is still no evidence of that, whereas the evidence that it saves lives by banishing malaria is irrefutable.

"Millions of lives were lost because we threw away our best weapon"

So did the world miss the chance to eradicate the disease? Today's public health scientists are not as gung-ho as their predecessors. "At first the goal of eradication did seem possible," says Roberts. "Yet when we look back, I think it is reasonable to conclude that global eradication was never achievable." It could never have succeeded in the Amazon, for instance, because too many people there did not have bedroom walls to be sprayed. But that didn't make the programme a failure, he insists. "A huge burden of disease and death was lifted from the Brazilian people. The disease hung on only in more remote and isolated rural areas."

In much of the world, he says, rates of malaria in the 1970s were probably as low as was achievable: "What the world failed to do was to sustain and build on the marvellous gains that had been achieved." So today in Brazil, there are hundreds of thousands of new cases each year in the Amazon basin, and the risk of malaria returning to southern Brazil is growing. The situation is far worse in much of Africa, where eradication never got going in the 1960s.

Some say DDT is doomed because mosquitoes will develop resistance: in the 1950s, Russell believed he had less than a decade before resistance took hold. Roberts says resistance is a problem, but mainly in areas where DDT was once widely used in agriculture. Where it was restricted to spraying inside homes there is little resistance, partly because the rates of spraying were orders of magnitude less.

Roberts has also now shown that DDT is uniquely effective in banishing malaria not because it kills mosquitoes but because it repels them. He published these findings in August this year – but notes that the observations were first made in 1953 by the entomologist Robert Muirhead-Thomson. Many lessons are being relearned.

It seems millions of lives have been lost because health experts threw away their best weapon. Are environmentalists to blame? There is no doubt that DDT was misused as an agricultural pesticide and seriously damaged wildlife. In that sense Carson was right. But regulators did not recognise that spraying indoors was different. And an environmental outcry against DDT helped to ensure that the early fears about its effect on human health became entrenched dogma long after they had been proved unfounded. **Fred Pearce** ●

The word

Zeroth theorem

PITY poor Johann Loschmidt, an Austrian scientist who calculated in 1865 that the number of molecules in a mole of gas is 6×10^{23}. This figure will be familiar to anyone interested in chemistry as Avogadro's number.

And yet the Italian chemist Amedeo Avogadro never calculated it. His name became attached to the number some years after Loschmidt's death, when a few chemists campaigned to name it in Avogadro's honour. The history of science is littered with such injustices over the credit taken for discoveries, so much so that historians of science have taken to categorising the slights.

The case of Loschmidt is a prime example of the zeroth theorem, which states that a discovery, rule or insight named after an individual often does not originate with that person. Others include the Dirac delta function, a mathematical trick used by engineer Oliver Heaviside 30 years before the English physicist Paul Dirac; the Lorentz gauge condition, an electromagnetic effect discovered by Ludvig Lorenz almost 40 years before Hendrik Lorentz published it in 1904; and Olber's paradox, that the night sky is dark even though the endless succession of stars in an infinite universe should fill the entire sky. German astronomer Heinrich Olber discussed it in 1823, but it was well known to Johannes Kepler more than 200 years before.

Another class of injustice results from the Matthew effect, by which eminent scientists get more credit for discoveries than lesser-known ones. The name comes from a passage in the Bible from the gospel according to Matthew: "For unto every one that hath shall be given... but from him that hath not shall be taken away."

STSCI/NASA

"The history of science is littered with injustices"

Consider, for instance, the career of Albert Schatz, who isolated the antibiotic streptomycin in 1943 only to see his supervisor Selman Waksman win a Nobel prize for the discovery in 1952. The effect may also have been at work when the British astronomer Jocelyn Bell Burnell discovered pulsars as a postgraduate in the 1960s. It was her supervisor, Anthony Hewish, who received the controversial Nobel prize in 1974. Bell's case might be more accurately attributed to the Matilda effect, however, which describes how the work of women in science is often neglected (named after 19th-century feminist Matilda Gage).

Several campaigns have sprung up to right the injustices of the zeroth theorem. Some physicists already refer to the Lorenz gauge condition, and Avogadro has been knocked off his perch in Germany, where 6×10^{23} is called the Loschmidt number.

Clearly, historians have a new effect to study, as the gospel according to Luke appears to have anticipated: "For whosoever exalteth himself shall be abased; and he that humbleth himself shall be exalted." The Luke effect, anyone? ●

Enigma

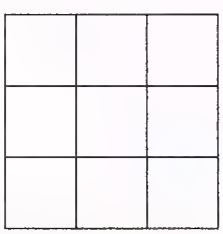
D for divisibility

No. 1463 Susan Denham

I HAVE placed each of the digits 1 to 9 in the grid on the right, with one in each little box. So I can read off 12 three-figure numbers; three from left to right across the rows, three from right to left, three from top to bottom in the columns, and three from bottom to top.

Now for each digit, D say, I have counted how many of those 12 numbers are exactly divisible by D. In each case the answer is itself divisible by D.

What are the highest and lowest of the 12 three-figure numbers?



£15 will be awarded to the sender of the first correct answer opened on Wednesday 7 November. The Editor's decision is final. Please send entries to Enigma 1463, New Scientist, Lacon House, 84 Theobald's Road, London WC1X 8NS, or to enigma@newscientist.com (please include your postal address). The winner of Enigma 1457 is David Hirst of Papakura, New Zealand.

Answer to 1457 Anglo-Italian sums
(a) OTTO is 2552 (b) DIECI is 10730
(c) DODICI is 101626

Bookends

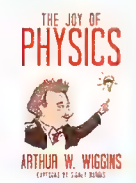
Hurricane warning

Storm World
by Chris Mooney, Harcourt,
ISBN 9780151012879
Reviewed by Jeff Hecht

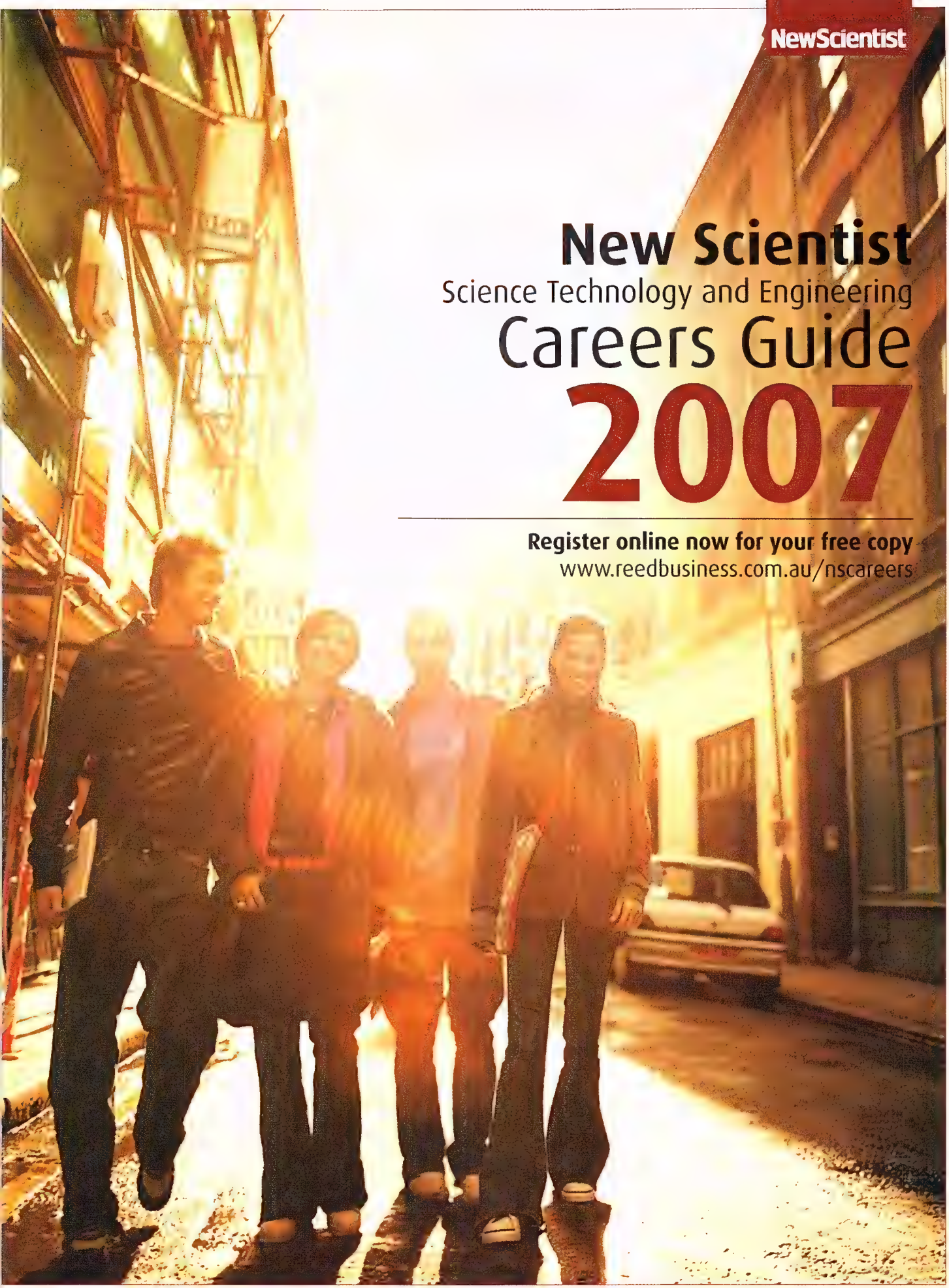
WILL climate change affect hurricanes? No doubt about it, writes Chris Mooney, but "precisely how and to what extent remains very much unsettled... and that makes all the difference". *Storm World* is as much about the process and politics of climate science as it is about hurricane research, and does a terrific job of explaining both. As a native of New Orleans, Mooney has a stake in the issue, but this book is no mournful warning of imminent doom. Instead, it reveals the debate between climate modellers and empirical meteorologists, explaining why their views diverge. Highly recommended.

Do try this at home

The Joy of Physics
by Arthur W. Wiggins, Prometheus,
ISBN 9781591025900
Reviewed by Valerie Jamieson



WHY is physics so worthwhile? For Arthur Wiggins, it is because it combines a quest to understand the universe, and the satisfaction of connecting ideas with reality through hands-on experiments, and the fascinating lives of physicists. Weaving all three together in this book makes for an entertaining, informative romp through electromagnetism and light, dynamics, quantum mechanics and the big bang. Wiggins, a physics professor, does not shy away from equations, so the book is best suited to adults who enjoyed the subject in their schooldays and want to rediscover its pleasures.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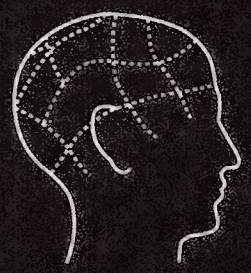

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Department of Health and Ageing
Therapeutic Goods Administration

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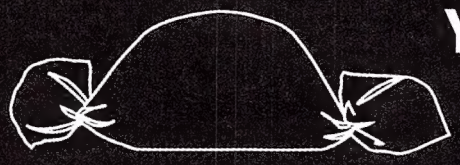

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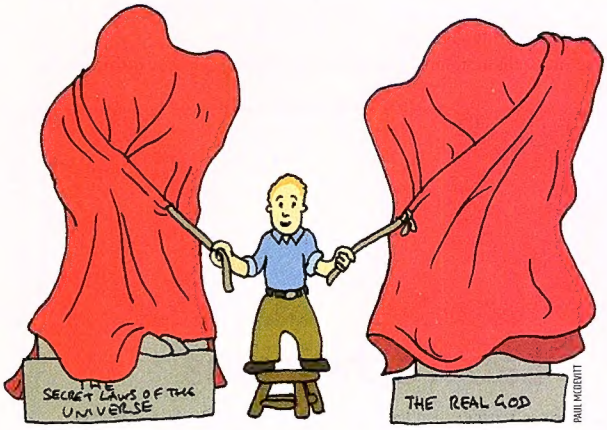

"ONE spring day towards the end of 2004, Rhonda Byrne discovered a secret – the secret laws and principles of the universe." Or so the Australian TV producer herself announces at www.thesecret.tv – which is, as suspicious readers may already have guessed, plugging a book and a DVD. These are inspired, she says, by a 1910 book written by one Wallace D. Wattles entitled *The Science of Getting Rich*.

The secret is, apparently, that "Money is magnetic energy. You are a magnet attracting to you all things." A clue as to how this attraction may be achieved is the outfit www.sedona.com, which offers a set of 20 CDs and a book on their version of "The Secret" for $388 – a saving of $1504 over the entrance fee for the four seminars reproduced in the CDs.

This sort of stuff cannot go unchallenged. And so we are led to www.TheSecretRevealedBook.com, which plugs yet another book, this time by James Garlow and Rick Marschall. They are scornfully dismissive: "Does the universe hold an age-old secret that has only recently been explained to humankind... by an Australian TV producer?"

They chart the "genealogy" of Byrne's secret, tracing its sources: "Occultism's Emerald Tablet, Hinduism and Phineas P. Quimby's 'New Thought' that emerged in the late 1800s". And then, they promise mysteriously that "...a trip to 'Mars Hill' will reveal the real God". Oh dear. So they've got a secret too – and we can't help wondering whether their chief objection to Byrne might be that they think she's a heretic.

Feedback's inclination is to pull up a chair, fire up the popcorn and watch them slug it out... Or we could cash in by setting up a course on "The secret method for uncovering the secret behind revealing the secret."

The label on reader Stilgherrian's Australian-made Starmaid ice-cube trays reassures him that they are "freezer safe" – which he says is "handy"

THE email that postgraduate researcher Hugh Datson received from the IT security coordinator at the University of Leeds placed him on the horns of a dilemma. Headlined "Identity Theft, Phishing & Email Scams", it warned him that: "Those who generate phishing emails are becoming increasingly sophisticated and ever more convincing; posing as charities, societies and web security controls within legitimate organisations, so it is important that you are always on your guard."

It concluded with this emphatic advice: "Never click on a link to a website that you find embedded in an email. It may look genuine but it could be a scam site designed to steal your identity or your money by one means or another. For more information on the 10 Golden Rules for IT Security see http://campus.leeds.ac.uk/informationsecurity."

You can appreciate Datson's predicament.

FOLLOWING our report of the letter from Lloyds TSB with a page containing the patently false statement "This page left deliberately blank" (26 May), several young readers have written to us from various parts of England saying that among their GCSE examination papers this summer there were pages containing a similar self-falsifying message. What's more, Andrew Munro's booklet of formulae and statistical tables for secondary school students has a page bearing the bare-faced lie "There is no text printed on this page".

The lie is now spreading to other media. Sara Butts was at Clapham Junction railway station in London recently, where her platform's electronic noticeboard displayed the message: "Because of a fault, no information can be displayed."

GEOFFREY CLARK purchased a Bosch IXO electric screwdriver supplied in a strong metal box. On opening the box he found the screwdriver held in place with a piece of tape marked "remove after opening the box". Clark wants to know how he could have done otherwise.

THANKS to Hannah Beardon for alerting us to this thought-provoking story of our times from the Ananova news service. "A Bosnian couple," we are told at www.ananova.com/news/story/sm_2512486.html, "are getting divorced after finding out they had been secretly chatting each other up online under fake names."

It seems that Adnan and Sana Klaric of Zenica made contact on a chat forum while using the names Prince of Joy

and Sweetie. They told each other how miserable they were because of their marriage problems and soon came to feel they had at last found the love of their lives. But it all fell apart when they agreed to meet up, each of them carrying a single rose by way of identification. They are now each filing for divorce on the grounds of the other's unfaithfulness.

FINALLY, a recycling bin spotted by Justin Maelzer in the city of Bath was marked "Mixed Glass Only". Maelzer was glad the bin was not empty on his arrival – he didn't want to work out how to put the first bottle in while still obeying the instructions.

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

The last word

Last Words past and present, plus a full list of unanswered questions, are available at www.newscientist.com

SACRED DNA

Animals and plants share a common genetic ancestry, so perhaps vegetarians who refuse to eat meat on ethical grounds should avoid anything that has DNA at all. Is this feasible? Could anybody suggest a menu?

I'm not aware of any living organisms that don't have DNA, so eating any tissues or cell cultures is pretty much ruled out. You could try eating RNA viruses, but you'd need to produce them in a cell culture, which generally requires animal serum to keep the cells alive. Your food wouldn't contain DNA, but you would have used dead animals to produce it.

One cheat that springs to mind is red blood cells. In many species, including humans, the nucleus and mitochondria are removed from these cells during the maturation process. This is to make room for more haemoglobin, the iron-bound protein that carries oxygen. Because the nucleus and mitochondria contain all the cell's DNA, you could argue that provided you don't kill the animals, drinking their blood is the ultimate vegetarian diet. You'd need to filter out the white blood cells, which still have plenty of DNA, but the rest of the blood components would be fine. They'd provide you with protein, some sugars and vitamins, but probably more iron than is healthy.

If that doesn't sound appealing, consider totally (bio)synthetic foods. Biologists routinely construct yeast and bacterial lines designed to churn out large quantities of a specific protein or other biological molecules. I assume it would be possible to scale this production up to produce sufficient quantities of purified proteins, sugars and so on to act as a food source. Don't expect it to be tasty, though: the proteins and sugars produced would be purified from the culture as crystalline powders. I'm not sure whether it's possible to produce fats like this without killing the cells, but if you did it would either be oil or a pretty nasty goo. Also, maintaining the cultures required to produce this stuff would rely on antibiotics to kill contaminant organisms, so going against the spirit of the idea.

Many, perhaps all, of the various vitamins and other nutrients we need could probably be synthesised in similar ways, given time and cash. The various mineral compounds we need – iron, copper, zinc, iodine and so on – are probably available from a good synthetic chemist. And, of course, you could drink milk. It's a complex mixture of secreted proteins, fats, sugars and pretty much everything else you need to stay alive. It may contain cells from the animal which produced it, but you could probably centrifuge these out.

Christopher Binny
By email, no address supplied

> "You could try baked retrovirus served on a water biscuit made from purified starch"

All I can come up with is a dish of baked retrovirus served on a water biscuit made from purified starch, fried in a purified fat of choice and seasoned with salt and vinegar. For the sweet course you might try a sorbet of snow sweetened with a purified sugar, honey or syrup, a touch of citric acid for bite, and with added vitamins, trace elements and essential oils to taste. It should be washed down with any spirit, or any wine or beer filtered to remove yeast traces.

Bryn Glover
Cracoe, North Yorkshire, UK

I found the following information on the wall of the Johnson Space Center in Houston, Texas. One cubic metre of lunar soil contains enough of the right elements to make a cheeseburger, an order of fries and a fizzy drink. That would contain no DNA, but might be a little expensive.

Graham Kerr
Glasgow, UK

I considered this some years ago and put my conclusions in the form of a cookery book, available online at www.cs.st-and.ac.uk/~norman/Shorts/inorganic.html.

Norman Paterson
Anstruther, Fife, UK

To whet your appetite, here's a recipe from Paterson's book – Ed

For four malachite burgers you will need:

Four slices of Welsh slate
1 kilogram of malachite

Cut the slates in two. Break up the malachite with a sledgehammer. Divide the malachite equally among four slates and cover with the remaining four. Bake at 1200 °C for 12 hours, by which time the malachite should be a beautiful bubbly green. Cool and eat. Excellent for picnics, as they can be prepared the century before. A dry gritty flavour.

Most people who are vegetarian on ethical grounds oppose killing of animals. They are rejecting the senseless deaths of the animals and the inhumane way the animals are treated, rather than worrying about similar DNA. Vegetarians have nothing against eating vegetable matter and fungi because these have no central nervous system and thus cannot experience pain.

Ceridwen Fitzpatrick
Perth, Western Australia

If all plants and animals have common DNA ancestry then perhaps we are all vegetarians. We are all also vegetables and for that reason the world is awash with cannibalism.

Indeed, vegetarians can eat their neighbours. By the "common DNA" logic this is no more or less cannibalistic than eating a radish. The only solution to this dilemma would be for every creature to subsist purely on non-living minerals and nutrients. Animals, however, are unlikely to stop eating what they want.

Brian Falconer
Aberdeen, UK

THIS WEEK'S QUESTION

Pants

In hot weather dogs keep cool by panting. If I were to do this I would hyperventilate and exhale too much carbon dioxide. How do dogs avoid the effects of respiratory alkalosis?

Andrew Benton
Birkenhead, Merseyside, UK

Questions and answers should be kept as concise as possible. We reserve the right to edit items for clarity and style. Please include a daytime telephone number and email address if you have one. Questions should be restricted to scientific enquiries about everyday phenomena. The writers of all published answers will receive a cheque for £25 (or the US$ equivalent). Reed Business Information Ltd reserves all rights to reuse question and answer material submitted by readers in any medium or format.

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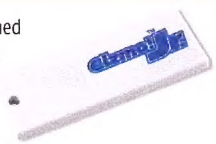
Memorable answer? The Last Word and New Scientist have teamed up with Crucial Technology (**www.crucial.com/uk**) and will be awarding each successful author a 2 GB Gizmo! flash drive.

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